Symbols—The following symbols are used throughout the course descriptions:

* ...... Courses in which graduate students may prepare Plan B projects.
, ...... The comma, used in prerequisite listings, means “and.”
† ...... All courses preceding this symbol must be completed before credit will be granted for any quarter of the sequence.
! ...... Work for this course will extend past the end of the term. A grade of K will be assigned to indicate that the course is still in progress.
§ ...... Credit will not be granted if credit has been received for the course listed after this symbol.
¶ ...... Concurrent registration is required (or allowed) in the course listed after this symbol.
# ...... Approval of the instructor is required for registration.
∆ ...... Approval of the department offering the course is required for registration.
❏ ...... Approval of the college offering the course is required for registration.
H .... Honors course.
f,w,s,su,UC ........ Following a course number indicate fall, winter, spring, summer, or University College (formerly Continuing Education and Extension).

A hyphen between course numbers (e.g., 3142-3143-3144) indicates a sequence of courses that must be taken in the order listed. A comma between course numbers (e.g., 1234, 1235, 1236) indicates a series of courses that may be entered any quarter. Courses numbered 8000 or above are open to graduate students only, except by special permission of the dean of the Graduate School.

If a course prerequisite statement specifies a class rank (e.g., 3rd year), no one below that rank may register for the course without special permission from the scholastic standards committee.

A prerequisite course listed by number only (e.g., prereq 5246) is in the same department as the course being described.

Special Interest Courses for IT Students (IofT)

IofT 1312. Exploration and Management of Careers in Science and Engineering. (2 cr; prereq current or prospective IT student)
Topics presented by employers and Career Services staff include career exploration using career development self assessments, career decision making, writing résumés and cover letters, identifying and contacting employers, interviewing, and using Career Services to find internships, co-ops, and permanent positions.

Aerospace Engineering and Mechanics (AEM)

AEM 1001f. Aerospace Engineering Orientation. (1 cr; prereq IT fr or soph; S-N only)
Fundamentals of aerospace engineering practice presented by professional engineers and members of the faculty.

AEM 1015f,w,s. Statics. (4 cr; prereq IT student, Phys 1251 or equiv, Math 1261)

AEM 3005f. Introduction to Flight. (4 cr, §1005; prereq IT student, Math 1252 or equiv, Phys 1252 or equiv)
Subsonic aerodynamics; standard atmospheric properties; generation of lift and drag; airfoils and finite wings; elements of airplane performance and stability; atmospheric flight mechanics and computer modeling of flight paths; design of a glider; determination of lift and drag from glider experiments.

AEM 3016f,w,s. Deformable Body Mechanics. (4 cr; prereq IT student, 1015, ¶Math 3261 or equiv)

AEM 3036f,w,s. Dynamics. (4 cr; prereq IT student, 1015, ¶Math 3261 or equiv)
Review of particle dynamics. Mechanical systems and the rigid-body model. Kinematics and dynamics of plane systems.

AEM 3200f,w. Introduction to Engineering Fluid Mechanics. (4 cr; prereq IT student, 1015, Math 3261 or equiv, Phys 1251 or equiv)
The flow of viscous incompressible fluids; fluid statics, Bernoulli flow, momentum conservation, laminar and turbulent pipe flow, laminar and turbulent boundary layers.

AEM 3281Hs. Introduction to Linear Systems. (4 cr, selection for IT honors program or consent of IT Honors Office)
Mathematical modeling of mechanical, hydraulic, and electromechanical systems; Laplace transforms, transfer functions, block diagrams, Bode graphs, time response of free and forced systems, numerical methods, frequency response, elementary concepts in feedback control.
AEM 3401f. Introduction to Dynamical Systems. (4 cr; §ME 3201; prereq IT student, 3036)
Mathematical modeling of mechanical, hydraulic, and electromechanical systems; Laplace transforms, transfer functions and block diagrams, time response of free and forced systems, elementary concepts in feedback control, frequency response.

AEM 5001su. Workshop: Elementary and Secondary Teachers. (4 cr; prereq educ major, inservice teacher [documentation required], ∆ limited to 30 students)
Lectures, film reviews, construction and demonstration of classroom aids, involvement with the NASA spacemobile, flight experience, and field trips covering such topics as satellites and probes, model rocketry including a launch, astronaut in space, principles of flight, conventional aircraft, space age education tools. Visits to local aerospace facility and to major aerospace installation in the country (subject to availability of airlift).

AEM 5200f. Kinematics and Dynamics of Fluid Flow. (4 cr; prereq upper div IT or grad student, 3036, §Math 3252)
First course in fluid mechanics. Includes stress and strain rate descriptions, fluid statics, use of differential and finite control volume analysis with continuity, momentum and energy equations, Bernoulli and Euler equations, introduction to Navier-Stokes equations, vorticity, potential flow.

AEM 5202s. Viscous Flow. (4 cr; prereq upper div IT, 5200)
Incompressible viscous flow using Navier-Stokes equations. Dimensional analysis; one-dimensional exact solutions; pipe flow; laminar and turbulent boundary layers, wakes, and jets; momentum integral; pressure gradients and separation; introduction to turbulence; Reynolds stresses.

AEM 5204f. Shock Waves and Compressible Fluid Flow. (4 cr; prereq upper div IT, 5200, ME 3301)

AEM 5205s. Aerospace Propulsion. (4 cr; prereq upper div IT, 5204, ME 3301)

AEM 5206w. Aerodynamics of Lifting Surfaces. (4 cr; prereq upper div IT, 5200, CSci 3101)
Pressure distributions, forces, and moments on airfoils and wings of finite span. Analysis of potential flow by thin airfoil theory, lifting line theory, and panel methods. Viscous effects and their relation to design variables.

AEM 5240. Rarefied Gas Dynamics. (4 cr; prereq IT or grad student, 5204 or ∆)
Relationship between continuum and molecular models for gas flow. Free molecule flows. Lift, drag, and energy transfer in free molecule flows. Slip flow and temperature jump.

AEM 5243s. Advanced Aerodynamics. (4 cr; prereq 5206)
Interaction between pressure distribution and boundary-layer growth on airfoils of arbitrary shape. Inviscid flow past non-planar wings of specified planform.

AEM 5244w. Hypersonic Aerodynamics. (4 cr; prereq upper div IT or grad student, 5204)

AEM 5250s. Computational Fluid Mechanics. (4 cr; prereq IT or grad student, FORTRAN, 5200)
Introduction to computational fluid mechanics with emphasis on finite element method; fundamentals of spatial discretization and numerical time-integration. Introduction to engineering and scientific computing environment and large-scale computing.

AEM 5300w. Flight Mechanics. (4 cr; prereq IT or grad student, 3005 or 5206)
Standard atmosphere, analysis of power required, the classical performance data, maximum and minimum speed, maximum rate of climb, angle of climb and glide, absolute ceiling, service ceiling of propeller and jet propelled aircraft. Static longitudinal stability, wing contribution, tail contribution, fuselage contribution, and the neutral point. Power effect and longitudinal control. Introduction to longitudinal dynamics.

AEM 5319s. Dynamics and Control of Aerospace Vehicles. (4 cr; prereq IT or grad student, 3401, 5300 or #)
Reference frames, kinematics and equations of motion. Forces and moments, trim, linearization and dynamic response characteristics for aircraft and spacecraft. Handling qualities. Aircraft stability derivatives, phugoid, short period, spiral, roll subsidence, and dutch roll modes, approximations and transfer functions.

AEM 5321w. Automatic Control. (4 cr; prereq 3401 or equiv)
Analysis and synthesis of automatic flight control systems for aerospace vehicles, longitudinal and lateral autopilots, stability augmentation systems, design by root locus, Nyquist and Bode techniques. Introduction to state space formulation.

AEM 5329. Fundamentals of Aerospace Vehicle Design. (4 cr; prereq AEM sr, 5300 or #)
Design process, design requirements, mission analysis, tradeoffs, sizing of vehicle components, weight estimates, performance, propulsion systems, weight and balance, stability and control, cost, ground and flight testing, compliance and certification. Students prepare a conceptual design of an aerospace vehicle and prepare a written report and oral presentation.

AEM 5330w, 5331s. Design of Aerospace Elements and Systems. (4 cr per qtr; prereq 4th-yr engineering major or ∆)
Group and individual design projects.

AEM 5359w. Deceleration of Aerospace Craft. (4 cr; prereq IT student, 3036, 5200)
Parachutes and other aerodynamic decelerators. Types, characteristics and applications, drag coefficients and steady descent, stability, deployment and opening forces, apparent mass effects, trajectory analysis, stress analysis, engineering properties of textile materials. Individual design projects.
AEM 5370w. Aerodynamics of V/STOL Flight. (4 cr per qtr; prereq 5206)
Aerodynamic characteristics of the classical rotor. Combinations of rotor-wing and direct thrust-wing configurations are analyzed for high-speed V/STOL aircraft. Jet flap, boundary layer control, and ground effect machines.

AEM 5410f. Introduction to Astrodynamics. (4 cr; prereq 3036)

AEM 5435s. Introduction to Random Vibrations. (4 cr; prereq 3401 or ME 3201)

AEM 5438f. Intermediate Dynamics. (4 cr; prereq 3036)
Three-dimensional Newtonian mechanics, kinematics of rigid bodies, dynamics of rigid bodies, analytical mechanics, generalized coordinates, holonomic constraints, Lagrange equations, and applications, multiple-degree-of-freedom dynamical systems.

AEM 5515w. Aerospace Structures I. (4 cr; prereq IT student, 3016)

AEM 5516s. Aerospace Structures II. (4 cr; prereq IT student, grade of C or better in 5515 or ∆)
Use of prepared computer programs for both microcomputers and main frame computers to solve moderately sized problems of analysis and design of trusses, plane frames, torsion, plane stress, and combination structures; elastic and inelastic analysis; use of symmetry and superposition to extend power of prepared programs; basis of the finite element methods used.

AEM 5518w. Mechanics of Composite Materials. (4 cr; prereq upper div IT student, 3016)
Analysis, design, and applications of laminated and chopped fiber reinforced composites. Micro- and macro-mechanical analysis of elastic constants, failure and environmental degradation.

AEM 5580f. Mechanics and Thermodynamics of Solids. (4 cr; prereq upper div IT or grad student, Math 3251)
Nonlinear continuum mechanics and thermodynamics in one dimension. Kinematics; mass, momentum, energy, and entropy; balance equations and jump conditions. Linear and nonlinear elastic constitutive equations. Applications drawn from wave propagation, stability, thermodynamics and Gibbs thermostatics, fracture mechanics, plasticity, and viscoelasticity.

AEM 5581w. Thermodynamics and Mechanics of Solids. (4 cr; prereq upper div IT or grad student, Math 3251)
Thermodynamics and mechanics of solids. Basic ideas of energy, power, heating, entropy, and stability; their use in formulating nonlinear constitutive equations and designing experiments. Analysis of shear-induced phase transitions and other instabilities. Other topics may include shock waves, solid-state engines, and other devices.

AEM 5630f. Aeromechanics Laboratory I: Fluid Mechanics. (4 cr; prereq upper div IT, 3016, 3036, 5200)
Experimental methods and design in fluid dynamics. Wind tunnel and water channel experiments involving flow visualization, pressure, velocity, and force measurement techniques. Computerized data acquisition, dimensional analysis, error analysis, data reduction methods. Written and oral lab reports required.

AEM 5631w. Aeromechanics Laboratory II: Solids and Structures. (4 cr; prereq upper div IT, 3016, 3036, 5200)
Experimental determination of stresses, strains, and displacements that occur in solids and structures. Error analysis, computerized data acquisition and analysis, strain gauges, photo-elasticity, material behavior, stress concentrations, composite materials. Written and oral lab reports required.

AEM 5632s. Aeromechanics Laboratory III: Dynamics and Controls. (4 cr; prereq upper div IT, 3016, 3036, 5200)
Experimental determination of dynamic response of systems and design and implementation of feedback controllers. Actuators and sensors for dynamic systems, digital signal processing, fast Fourier transforms. Written and oral lab reports required.

AEM 5650s. Aeroelasticity. (4 cr; prereq 5206)
Static aeroelastic phenomena, torsional divergence of a lifting surface, control surfaces reversal and elastic efficiency. Effects of elastic deformations on stability, aeroelastic twisting of propeller blades and rotary wings, theory of lifting surface flutter, problems of gust response and buffeting, scaling of aeroelastic force models.

AEM 5687f. Introduction to Acoustics and Environmental Noise. (4 cr; prereq upper div IT or grad student, Phys 1253 or equiv, Math 3361 or equiv)
Derivation of the wave equation, plane wave solution, transmission and reflection at boundaries, resonators and mufflers, three-dimensional wave propagation, properties of environmental noise sources, hearing and perception of sound, acoustical properties of rooms, lab experience in sound and noise measurements and noise control techniques.

AEM 5800, 5801, 5802f, w,s. Problems in Mechanics and Materials. (1-4 cr per qtr; prereq ∆)
Topics of current interest. Individual projects with consent of faculty sponsor.

AEM 5810, 5811, 5812f, w,s. Problems in Fluid Mechanics. (1-4 cr per qtr; prereq ∆)
Topics of current interest. Individual projects with consent of faculty sponsor.

AEM 5821H, 5822H. Aerospace Engineering and Mechanics Honors Thesis I-II. (4 cr; prereq upper div AEM honors student, ∆)
Individual projects under the direction of a member of the AEM faculty.
AEM 5838, 5839. Summer Engineering Employment. (1-4 cr per qtr; prereq completion of 3rd yr, A) Written report based on summer work in an engineering field (not less than 360 hours per summer).

AEM 5840-5841-5842-5843. Industrial Assignment. (2 cr per qtr; prereq regis in engineering intern program, A) Engineering intern industrial lab. A formal technical report, covering the work during the industrial assignment, is required.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
AEM 8001, 8002, 8003. Seminar: Aerospace Engineering and Mechanics
AEM 8201, 8202, 8203. Fluid Mechanics I-III
AEM 8209. Rotating Fluids
AEM 8216, 8217. Theory of Turbulence I-II
AEM 8219. Computers in the Laboratory
AEM 8220. Rheological Fluid Mechanics I
AEM 8221. Rheological Fluid Mechanics II
AEM 8232. Physical Gas Dynamics
AEM 8240. Perturbation Methods in Fluid Mechanics
AEM 8250. Computational Aerodynamics
AEM 8260. Nonlinear Waves in Mechanics I
AEM 8410. Advanced Dynamics
AEM 8411. Linear Systems
AEM 8412. Nonlinear Systems
AEM 8413. Advanced Nonlinear Systems
AEM 8414. Hamiltonian Systems on Manifolds
AEM 8420. Trajectory Optimization Techniques
AEM 8421. Modern Control Theory for Aerospace Systems
AEM 8422. Robust Multivariable Control Design
AEM 8425. Advanced Topics in Aerospace Guidance and Control
AEM 8501, 8502, 8503. Research Seminar in the Mechanics of Materials
AEM 8510. Continuum Mechanics I
AEM 8511, 8512. Continuum Mechanics II-III
AEM 8522. Theory of Plasticity
AEM 8540. Theory of Viscoelasticity
AEM 8570. Fracture Mechanics
AEM 8585. Advanced Topics in Continuum Mechanics
AEM 8589. Mechanics of Crystalline Solids
AEM 8594. Elastostatics I
AEM 8595. Elastostatics II
AEM 8596. Elastodynamics
AEM 8601. Finite Element Methods in Computational Mechanics
AEM 8602. Finite Element Methods in Computational Fluid Mechanics
AEM 8777. Thesis Credits: Masters
AEM 8800, 8801, 8802. Selected Topics in Mechanics and Materials
AEM 8810, 8811, 8812. Selected Topics in Fluid Mechanics
AEM 8820, 8821, 8822. Selected Topics in Dynamical Systems and Controls
AEM 8880. Thesis Credits: Doctoral
AEM 8888. Plan B Project

Astronomy (Ast)
Ast 1011. Descriptive Astronomy. (4 cr, §1021, §1031, §1032; 4 lect hrs per wk) The sun, the moon, the planets and their relationships; stars, galaxies, cosmology, and the physical universe.

Ast 1015. Descriptive Astronomy Laboratory. (1 cr, §1025H; prereq high school algebra; high school trigonometry recommended; 1 lab hr per wk) The human place in the universe. Study of Earth as a planet, other planets, the sun, stars, galaxies. Background and fragility of life on Earth. Scale, origin, and history of the universe and our relationship to it.


Ast 1021H. Introduction to Astronomy. (4 cr, §1011, §1031, §1032; prereq high school trigonometry and physics or chemistry; 3 lect, 2 lab hrs per wk) Solar system, stars, galaxies, and cosmology. A more mathematical and physical discussion than 1011.

Ast 1031. Exploring the Universe A. (4 cr, §1011, §1021H, §1032; 3 lect, 1 active learning session hrs per wk) The human place in the universe. Study of Earth as a planet, other planets, the sun, stars, galaxies. Background and fragility of life on Earth. Scale, origin, and history of the universe and our relationship to it.

Ast 1032. Exploring the Universe L. (4 cr, §1011, §1021H, §1032; 3 lect, 2 lab hrs per wk) The human place in the universe. Study of Earth as a planet, other planets, the sun, stars, galaxies. Background and fragility of life on Earth. Scale, origin, and history of the universe and our relationship to it.
Ast 1040. Mathematics and Our Universe. (4 cr; 3 lect hrs, 1 active learning session hr per wk) Exploration of selected topics in astronomy to illustrate how basic mathematical concepts and reasoning are used to further our understanding of the universe. Emphasis on using an intellectually stimulating discipline to introduce and explore mathematical modes of thinking.

Ast 3051. Astrophysics. (4 cr; prereq 1 yr calculus, Phys 1254 or #) The solar system, stellar systems, galaxies and extragalactic universe. How information is obtained; conclusions that can be inferred from observations through applications of elementary physics to astronomical problems.

Ast 3970. Directed Studies. (1-5 cr; prereq #, A) Independent, directed study in observational and theoretical astrophysics areas arranged by student with faculty member.

Ast 5061. Computational Methods in the Physical Sciences I. (4 cr, §Phys 5061; prereq CLA Jr or sr or upper div IT or grad student or #; 2 lect, 6 lab hrs per wk) Introduction to the solution of problems in the physical sciences with computer programs. Selected numerical methods and general spirit of mapping problems onto computational algorithms. Arranged lab at scientific computer work station.

Ast 5062. Computational Methods in the Physical Sciences II. (4 cr, §Phys 5062; prereq Phys/Ast 5061, CLA Jr or sr or upper div IT or grad student or #; 2 lect, 6 lab hrs per wk) Introduction to advanced techniques in computer simulation through examples from classical statistical mechanics, classical electrodynamics, and fluid dynamics. Computer experiments using SUN systems and their graphics capabilities.


Ast 5164. Extragalactic Astronomy. (4 cr; prereq 5163 or #) Structure and evolution of external galaxies. Classification, stellar and gaseous contents, kinematics and dynamics, extragalactic distance scale, clusters, galactic nuclei and associated activity.

Ast 5165. Cosmology. (4 cr; prereq Phys 3513 or #) Large-scale structure and history of the universe. Introduction to Newtonian and relativistic world models, Big Bang model, microwave background, physics of early universe; cosmological tests, measurement of Hubble constant and deceleration parameter, galaxy formation.

Ast 5201s. Methods of Experimental Astrophysics. (4 cr; prereq 3051, Phys 3513; 2 lect, 6 lab hrs per wk) Contemporary astronomy techniques and instrumentation. Students make astronomical observations that include data acquisition and instrument control using facilities at O’Brien Observatory as well as data reduction and image processing using department computing facilities.

Ast 5299H. Senior Honors Astrophysics Research Seminar. (1 cr; prereq IT or CLA upper div honors student, #; 1 seminar hr per wk; S-N only) An honors opportunity for upper division astronomy and astrophysics majors in the honors program, based on the departmental research seminar.


Ast 5590. Directed Studies. (1-5 cr; prereq #, A) Independent, directed study in observational and theoretical astrophysics in areas arranged by the student with a faculty member. Intended for senior astrophysics majors.

Ast 5590. Directed Research. (3 cr minimum; prereq #, A) Independent research in observational or theoretical astrophysics under the direction of a faculty member. Intended for senior astrophysics majors.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

Ast 8200.* Seminar: Astrophysics and Space Physics
Ast 8481, 8482, 8483.* Topics in Astrophysics
Ast 8990. Research in Astronomy and Astrophysics
Phys 8081-8082.* General Relativity
Phys 8161.* Atomic and Molecular Physics
Phys 8163-8164.* Plasma Physics
Phys 8400.* Seminar: Cosmic Ray and Space Physics
Phys 8411-8412.* Cosmic Ray and Space Physics
Phys 8421-8422.* Solar and Magnetospheric Physics
Biosystems and Agricultural Engineering (BAE)

BAE 1060. Biosystems and Agricultural Engineering Orientation. (1 cr; S-N only; 2 hrs per wk) Introduction to the profession through lectures, readings, discussions, and presentations by faculty, practicing engineers, and fellow students. For students interested in majoring in biosystems and agricultural engineering or exploring the profession. Discussion of various areas of specialization along with the environment, safety, ethics, and professionalism. Identification of internships, employment opportunities, and advanced studies.

BAE 3031. Computations in Biosystems and Agricultural Engineering. (4 cr; prerequisite IT student, CSci 3101, CSci 3102 or CSci 3113, Math 3261 or MMath 3261; 3 lect, 2 rec hrs per wk) Computational techniques applied to biosystems and agricultural engineering problems: spreadsheets, elementary numerical methods, computer drafting, engineering economics, selected engineering software. Effective presentation of quantitative and graphical information.

BAE 3052. Engineering Principles of Soil-Water-Plant Systems. (4 cr; prerequisite IT student, 3031, AEM 3200 or CE 3400, Biol 1009; 3 lect, 3 lab hrs per wk) Mechanical and hydraulic properties of soil; moisture relations; strength parameters for structural and mechanical design. Soil-machine action in tillage and traction. Energy and water balance in the soil-water-plant system. Plant structure and growth. Engineering and management requirements.

BAE 3150. Biology for Engineering. (4 cr; prerequisite IT student, 3031, Biol 1009, ME 3301 or MME 3301; 3 lect, 3 lab hrs per wk) Understanding biology in terms of mathematics, chemical reactions, transport phenomena, material science, mechanics, and electronics. Applications to engineering.

BAE 3970. Directed Studies in Biosystems and Agricultural Engineering. (1-5 cr; prerequisite #) Independent study of topic(s) involving physical principles as applied to agricultural production and land resources.

BAE 5050. Intern Reports. (2 cr per qtr; S-N only; prerequisite IT or COAFES student in BAE, #) Student exposure to engineering practice through an intern program. Engineering reports on work assignments are reviewed by faculty and coordinated with industry advisers.

BAE 5070. Instrumentation and Control for Biological Systems. (4 cr; prerequisite upper div IT or wood and paper science major or grad, EE 1400, EE 3009, ME 3900 or Stat 3091; 3 lect, 2 lab hrs per wk) Measurement of motion, force, pressure, flow, temperature, size, shape, color, texture, rheology, moisture, water mobility, fat, and pH. Control principles and instrumentation for biological systems. Linking of physical and biological control systems.

BAE 5072. Finite Element Method: Fundamentals and Applications. (4 cr; prerequisite upper div IT or grad IT major, Math 3261; 4 lect hrs per wk) Basic theory and principles of implementation of the finite element method for a number of fundamental engineering areas. Applications in heat transfer, fluid mechanics, solid mechanics, radial and axisymmetric field problems, and time-dependent field problems.

BAE 5074. Microcomputer Interfacing. (4 cr; prerequisite upper div IT or grad IT major, CSci 3101, CSci 3102 or CSci 3113, EE 1400, EE 3009; 2 lect, 4 lab hrs per wk) Introduction to digital components, integrated circuits, and microcomputers. Interfacing of microcomputers for data acquisition and control.

BAE 5140. Thermal Processes for Food. (4 cr; prerequisite upper div IT or grad IT major, Chem 5103 or ME 5342; 3 lect, 3 lab hrs per wk) Engineering principles of thermal processing of food, pasteurization, microwave heating, heat exchange, evaporation, refrigeration, and freezing. Process design and evaluation.

BAE 5191-5192. Special Problems in Biosystems and Agricultural Engineering. (1-5 cr per qtr; prerequisite #) Individual study project at an advanced level involving application of engineering principles to a specific problem.

BAE 5350. Agricultural Machinery and Terramechanics. (4 cr; prerequisite upper div IT or grad IT major, AEM 3016, AEM 3036; 3 lect, 3 lab hrs per wk) Engineering principles governing the performance of machinery used in agriculture. Emphasis on soil-machine interaction (traction and tillage), off-road vehicle dynamics, operator-machine interaction, drive-line design, power unit selection, and duty cycle analysis.

BAE 5540. Watershed Engineering. (4 cr; prerequisite upper div IT or grad IT major, 3052 or CSci 3052 or CE 3300, CE 3400; 3 lect, 3 lab hrs per wk) Application of engineering principles to the management of surface runoff and soil water in agricultural, range, and urban lands. Design of facilities for control of surface runoff to mitigate problems of flooding and degradation of surface water quality.

BAE 5550. Water Management Engineering. (4 cr; prerequisite upper div IT or grad IT major, 3052 or CSci 3300, CE 3400; 3 lect, 3 lab hrs per wk) Application of engineering principles to the management of water for production and environmental protection in agricultural systems. Design of facilities to irrigate and drain croplands and to enhance water quality.

BAE 5560. Mechanics of Flow in the Unsaturated Zone. (4 cr; prerequisite upper div IT or grad IT or COAFES grad student, Math 3261, Soil 5232 or #; 3 lect hrs per wk) Fluid retention and transmission properties of unsaturated porous media. Equations of mass conservation and Darcy’s law for unsaturated porous media. Simultaneous flow of immiscible fluids. Analytical, finite difference, and finite element solutions to the governing equations.

BAE 5751. Biochemical Engineering I. (3 cr, §ChEn 5751; prerequisite BAE major or grad ChEn major or #; 3 lect hrs per wk) Application of material and energy balances and concepts from thermodynamics, kinetics, and transport phenomena to cellular and enzyme systems.

BAE 5891. Senior Design I. (3 cr; prerequisite upper div IT, 20 cr BAE completed or in progress; 4 rec hrs per wk) Introduction to design processes. Safety and ethics in design. Development of a proposal for a senior design project (individual or group). Poster presentation of proposal to the department at mid-quarter. Development of project specifications, time line, and concepts for the design. Review of case studies, constructive review of existing designs.
CHEMICAL ENGINEERING

BAE 5892. Senior Design II. (3 cr; prereq 5891; 4 rec hrs per wk)
Completion of a design project started in BAE 5891 culminating in a design report and poster display of the final design. Continuation of the development of design methodology including decision making, hazard analysis, and detailed system descriptions.

BAE 5910. Agricultural Waste Management Engineering. (4 cr; prereq upper div IT or grad IT major, 3052; 3 lect, 3 lab hrs per wk)
Sources and characteristics of agricultural wastes including livestock, food processing, and domestic wastes. Physical, biological, chemical, rheological, and microbiological properties. Effects on the environment. Collection, storage, treatment (aerobic and anaerobic), and utilization/disposal. Land application of livestock and food processing wastes, municipal effluents, and sludges. On-site sewage treatment.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

BAE 8000. Supervised Teaching Experience

BAE 8100. Seminar

BAE 8190, 8191, 8192. Advanced Problems and Research

BAE 8500. Hydrologic Modeling—Small Watersheds

BAE 8700. Coupled Moisture, Heat, and Chemical Transfer in Porous Media

Chemical Engineering (ChEn)

ChEn 3001. Programming for Computational Methods. (2 cr; prereq ChEn or MatS major; 1 lect, 2 lab hrs per wk)
Programming and computing topics relevant for implementing numerical methods for mathematical equations encountered in chemical engineering and materials science. Computer usage (developing, debugging, and running code), programming in FORTRAN, generating graphics.

ChEn 3090, 3091, 3092. Industrial Employment.
(1-2 cr depending on duration of employment and character of professional training received)
Employment with chemical industry, opportunity for professional training in chemical engineering. Report covering work period required.

ChEn 5001. Computational Methods in Chemical Engineering and Materials Science. (4 cr, §MatS 5001; prereq ChEn or MatS major, 3001 or FORTRAN course; 3 lect, 2 computer lab hrs per wk)
Analysis of representative chemical engineering problems by computer and mathematical methods.

ChEn 5101. Principles of Chemical Engineering I. (4 cr; prereq ChEn major, Chem 3302, Chem 3306, Math 3261, Phys 1253; 3 lect, 2 rec hrs per wk)
Material and energy balances applied to chemical engineering systems.

ChEn 5102. Principles of Chemical Engineering II. (4 cr; prereq upper div ChEn major, 5001, 5101; 3 lect, 2 rec hrs per wk)
Fluid dynamics and its applications to chemical engineering unit operations.

ChEn 5103. Principles of Chemical Engineering III. (4 cr; prereq upper div ChEn or MatS major, 5102; 3 lect, 2 rec hrs per wk)
Heat and mass transfer and its applications to chemical engineering unit operations.

ChEn 5104. Unit Operations and Separation Processes. (4 cr; prereq upper div ChEn or MatS major, 5103, 5201; 3 lect, 2 rec hrs per wk)
Absorption, extraction, distillation, stagewise and continuous separations.

ChEn 5201. Thermodynamics and Material States. (4 cr; prereq upper div ChEn major, 5001, 5101, Chem 5534 or §; 3 lect, 2 rec hrs per wk)
Principles of thermodynamics applied to closed and open systems and to equilibrium states of homogeneous and heterogeneous substances, gases, liquids, and solids.

ChEn 5202. Chemical Engineering Thermodynamics and Kinetics. (4 cr; prereq upper div ChEn major, 5201; 3 lect, 2 rec hrs per wk)
Chemical equilibrium and chemical kinetics applied to chemical engineering systems.

ChEn 5301. Chemical Reactor Analysis. (4 cr; prereq upper div ChEn major, 5202; 3 lect, 2 rec hrs per wk)
Principles of reactor design for homogeneous and heterogeneous reactions. Analysis of reactors from a kinetic and thermodynamic point of view.

ChEn 5302. Applied Reactor Analysis. (4 cr; prereq 5301 or equiv)
Practical chemical reaction systems and the reactors for them. Catalysis and its role in the chemical industry. Analysis of functioning chemical reaction systems involving ammonia synthesis, polymerization reactors, combustion, and sulfur dioxide removal.

ChEn 5401. Chemical Engineering Laboratory. (4 cr per qtr; prereq upper div ChEn major, 5102, §5103; 4 lab, 1 lect, 1 lab conf hrs per wk)
Applications of unit operations; principles of fluid flow, heat and mass transfer; experiments with reports.

ChEn 5402. Chemical Engineering Laboratory. (4 cr per qtr; prereq upper div ChEn major, 5401; 4 lab, 1 lect, 1 lab conf hrs per wk)
Applications of unit operations; principles of fluid flow, heat and mass transfer; experiments with reports.

ChEn 5455. Electrochemical Engineering. (4 cr, §MatS 5455; prereq upper div IT or grad, 5201 or MatS 5101 or §; 4 lect hrs per wk)
Electrokinetics, thermodynamics of cells, practical and advance cells (batteries), fuel cells, electrolysis, modern sensors.

ChEn 5501. Process Evaluation and Design. (4 cr; prereq upper div ChEn major, 5104, 5301, 5402; 3 lect, 3 design lab hrs per wk)
Dynamics of chemical engineering industries, economics of process evaluation, bases for cost estimations. Plant designs prepared and compared with actual installations. Special applications of unit operations, reaction kinetics, and thermodynamics.
ChEn 5502. Process Evaluation and Design. (4 cr; prereq upper div ChEn or MatS, major, 5501, 5601; 3 lect, 2 design lab hrs per wk)
(Continuation of 5501) Computer-aided design of unit operations, chemical reactors and integrated plants; operability characteristics of chemical processes; design for optimum operability (safety, reliability, control).

ChEn 5601. Process Control. (4 cr; prereq upper div ChEn major, 5104, 5301 or #; 3 lect, 2 rec hrs per wk)
Elementary theory of control and its application to chemical processes. Synthesis of feedback control loops for linear systems.

ChEn 5603. Process Control. (3 cr; prereq 5601 or #; 3 lect hrs per wk)
Advanced topics in chemical process control; synthesis of control structures; multivariable control schemes, optimal control and estimation; computer-aided real-time process control.

ChEn 5604. Process Control Laboratory. (2 cr; prereq 5601)
Experiments designed to illustrate and apply control theory. Measurement techniques, calibration, tuning of controls, characterization of sensors and control circuits.

ChEn 5640. Polymerization Reactor Engineering. (3 cr; prereq ChEn reactor design course or #; 3 lect hrs per wk)
Analysis and design of polymerization reactors. Mathematical modeling techniques, chain-growth and step-growth polymerization, copolymerization, composition and sequence distributions, and molecular weight distributions with emphasis on nonlinear polymerization and network formation.

ChEn 5751. Chemical Engineering in Biotechnology and the Environment. (3 cr; prereq ChEn sr or grad or #; 3 lect hrs per wk)
Applications of material and energy balances and concepts from thermodynamics, kinetics, and transport phenomena to cellular and enzyme systems.

ChEn 5753. Bioseparations. (3 cr; prereq Biol 5001, ChEn sr or grad or #; 3 lect hrs per wk)
Description and analysis of methods of separation of biochemical products of cellular and enzyme activity; applications to process synthesis.

ChEn 5754. Food Processing Technology. (4 cr; prereq 5103 or #; 3 lect hrs per wk)
Heat transfer in food processing; protein processing; financial evaluation of projects; case studies; discussions of marketing, government regulation, nutrition.

ChEn 5756. Biochemical Engineering Laboratory. (2 cr; prereq 5751 or 5752; 4 lab hrs per wk)
Lab projects involving studies of microbial growth; biochemical product formation, isolation, and purification; medium sterilization.

ChEn 5761. Science and Technology of Porous Media. (3 cr; 3 lect hrs per wk)
Fundamentals of structure of porous media and of flow, transport, and deformation in them. Relations of macroscopic properties and behavior to underlying microscopic structures and mechanisms. Examples from nature and technology, with special reference to in situ processing and enhanced recovery.

ChEn 5771. Colloids and Dispersions. (3 cr; prereq physical chemistry; 3 lect hrs per wk)
Preparation, stability, and coagulation kinetics of colloidal solutions. Topics include DLVO theory, electrokinetic phenomena, and properties of micelles and other microstructures.

ChEn 5774. Interfacial Phenomena of Liquids. (3 cr; prereq physical chemistry, 5102 or equiv; 3 lect hrs per wk)
Surface tension, surface geometry and capillarity, thin-films and disjoining pressure, contact angle; capillarity-driven and surface tension gradient-driven flows; wetting, spreading, dewetting and retraction; surfactant effects; fluid displacement, detergency, flotation, dynamic wetting, entrainment, adhesion. Examples from science and technology.

ChEn 5780. Principles of Mass Transfer in Engineering and Biological Engineering. (3 cr; prereq upper div engineering or science major)
Principles of mass transfer in gases, liquids, biological and macromolecular solutions, gels, solids, membranes, capillaries, and porous solids. Interaction between mass transfer and chemical reaction. Applications in biological, environmental, mineral, chemical engineering systems.

ChEn 5810. Processing of Electronic Materials. (3 cr; prereq MatS 5011 or #; 3 lect hrs per wk)
Materials science and chemical engineering aspects of processing of materials for microelectronic devices (e.g., semiconductor memories, microprocessors) and optical devices (e.g., semiconductor lasers, optical wave guides).

ChEn 5902, 5903, 5904, 5905. Special Topics. (Cr ar; 1 conf hr per wk, lab hrs ar)
Investigations in chemical engineering. Library or lab research.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

ChEn 8004. Physical Rate Processes

ChEn 8005. Physical Rate Processes

ChEn 8101. Intermediate Fluid Mechanics

ChEn 8102. Problems in Fluid Mechanics

ChEn 8104. Interfaces and Interfacial Phenomena

ChEn 8105. Principles and Applications of Rheology

ChEn 8201-8202-8203. Advanced Mathematics for Chemical Engineers

ChEn 8301-8302. Physical and Chemical Thermodynamics

ChEn 8401-8402. Chemical Reaction Kinetics—Kinetics of Homogeneous Reactions

ChEn 8403. Chemical Reaction Kinetics—Advanced Topics

ChEn 8601-8602-8603. Molecular Theory of Equilibrium and Nonequilibrium Processes

ChEn 8640. Polymerization Reactor Engineering
Chem 1051-1052. Chemical Principles I-II. (4 cr per qtr; primarily for science or engineering majors; prereq 1001 or passing placement examination; 3 lect, 1 lab discussion, one 3-hr lab per wk)
Atomic theory; periodic properties of elements; chemical thermodynamics; development of structural concepts; geometry of molecules; bonding theory; behavior of gaseous and liquid states; solid state and materials; chemistry; dynamics; equilibrium; behavior of solutions; acids and bases; descriptive chemistry of elements and compounds; applications to environmental problems.

Chem 1051H-1052H. Honors Chemical Principles I-II. (4 cr per qtr; prereq selection for IT honors curriculum or consent of IT Honors Office, 1001 or passing placement examination; 3 lect, 1 lab discussion, one 3-hr lab per wk)
For description see 1051-1052.

Chem 3100. Quantitative Analysis Lecture. (3 cr; for non-chemistry majors; prereq 1052; 3 lect hrs per wk)
Introduction to the theory of quantitative chemical analysis.

Chem 3101. Quantitative Analysis Laboratory. (2 cr; prereq 3100 or 33100; two 4-hr labs per wk)
Introductory lab in quantitative chemical analysis.

Chem 3301. Organic Chemistry I. (4 cr; prereq 1052 or equiv; 4 lect hrs per wk)
Reactions of organic compounds, nucleophilic substitution and addition; electrophilic substitution and addition; elimination reactions; molecular arrangements; oxidation and reduction.

Chem 3302. Organic Chemistry II. (4 cr; prereq 3301, 3305 or 3305; 4 lect hrs per wk)
Important classes of organic compounds, their constitutions, configurations, and conformations; relationship between molecular structure and chemical reactivity.

Chem 3303. Organic Chemistry III. (4 cr; prereq 3302, 3305 or 3305; 4 lect hrs per wk)
Chemical reactivities and methods for the synthesis and structural characterization of biologically important classes of organic compounds such as lipids, carbohydrates, amino acids, peptides, proteins, nucleotides, nucleosides, and nucleic acids.

Chem 3305. Organic Chemistry Laboratory I. (2 cr; prereq 3301 or §3301; 1 lab conf, one 4-hr lab per wk)
Lab techniques used in the preparation, purification, and characterization of typical organic substances.

Chem 3306. Organic Chemistry Laboratory II. (2 cr; prereq 3302 or §3302, 3305; 1 lab conf, one 4-hr lab per wk)
Continuation of 3305.

Chem 3335H-3336H. Honors Organic Chemistry Laboratory. (5 cr for sequence, §3305, §3306, §3336; prereq 3301 or §3301, # Chem, ChEn, BioC majors only; A-F only)
Honors organic chemistry lab to take the place of 3305, 3306, and 3336.

Chem 3336. Organic Chemistry III Laboratory. (3 cr; prereq 3302, 3306; A-F only; 1 lect, two 4-hr labs per wk)
Emphasis on the use of instrumentation routinely used in support of experimental work in organic chemistry.
COURSE DESCRIPTIONS

Chem 3701 (formerly 5731). Introduction to Inorganic Chemistry. (4 cr; prereq 3302 or 5302; 4 lect hrs per wk)
Introduction to inorganic chemistry. Periodic trends. Structure and bonding concepts in compounds in which s and p electrons are important. Descriptive chemistry of solids and transition metal compounds.

Chem 3970. Directed Study. (Cr ar; prereq #)
On- or off-campus learning experiences, individually arranged between a student and chemistry faculty member, in areas not covered by regular courses.

Chem 3991, 3992, 3993. Special Topics in Chemistry. (1 cr; prereq 1 qtr 1xxx-level chem or #; 5-N only; 1 lect per wk)
Topics in chemistry—opportunities and current research.

Chem 5001-5002. Chemistry Concepts for Junior High School Teachers. (4 cr; prereq college-level general chem, secondary school tchg exper or #; restricted to secondary school teachers or College of Education and Human Development students)
Chemistry fundamentals to augment and expand the resources of junior high school science teachers for the teaching of chemistry concepts. Emphasis on demonstration of chemical ideas by experiments and selecting chemistry topics appropriate for junior high school students.

Chem 5122. Advanced Analytical Chemistry. (4 cr; prereq 3302, 5501 or 5534; 3 lect hrs per wk)
Equilibria in aqueous and nonaqueous systems.

Chem 5126. Modern Analytical Chemistry. (4 cr; prereq 3302, 3306, ChEn major only; two 1½-hr lect, one 4-hr lab per wk)
Strategies and techniques for solving modern analytical problems. Use of modern instruments in analysis.

Chem 5127. Analog Instrumentation. (5 cr; prereq Chem major or grad, Phys 1253, Math 3251 or equiv or #; three 1½-hr lect, one 3-hr lab per wk)
Basic principles of electronic circuitry; servo systems, operational amplifiers, feedback control, oscillators, and converters for signal processing and control of chemical measurement systems.

Chem 5128. The Small Computer in the Chemical Laboratory. (5 cr; prereq 5127 or #; two 1½-hr lect, two 4-hr labs per wk)
Applications of the lab computer to the control of chemical instrumentation and acquisition of data. Hardware (interfacing) and software (assembly language programming) of automating the chemical experiment.

Chem 5130. Analytical Chemistry. (3 cr; prereq 3302, 3306; 3 lect hrs per wk)
Primarily for chemistry majors. Methods and concepts of measurement by chemical and instrumental analysis, including titrimetry, quantitative spectrophotometric analysis, chromatographic separations, and equilibrium and rate methods emphasizing applications to organic and biochemical systems.

Chem 5131. Analytical Chemistry Laboratory. (2 cr; prereq 5130 or #5130; two lab lect, two 3-hr labs per wk)
Lab for 5130. High precision methods, acidimetry and complexometry, single and multicomponent analysis by spectrophotometry, analysis of mixtures by ion exchange and gas chromatography, enzymatic and rate methods.

Chem 5133. Chemical Instrumentation and Analysis Lecture. (3 cr, §5126; prereq 5130, 5131, 5501 or 5534; 3 lect hrs per wk)
Methodology and practices of solving analytical problems. Application of modern instrumental techniques.

Chem 5139. Chromatography and Separation Science. (4 cr; prereq Chem major or grad, 5133, 5140 or equiv or #; three 1½-hr lect per wk)
Fundamental and practical aspects of gas liquid chromatography, modern liquid chromatography, and other techniques used for analysis and separations.

Chem 5140. Chemical Instrumentation and Analysis Laboratory. (3 cr, §5126; prereq 5133, Chem major; 1 rec, two 4-hr labs per wk)
Instrumental techniques including spectroscopic methods of analysis, electrochemical methods of analysis, and analysis based on separation. Emphasis on the use of computers in data collection and reduction.

Chem 5211. Introduction to Materials Chemistry. (3 cr; prereq 3301, 5133, or #)
Structure and molecular routes to solids, including CVD and sol-gel processing; self-assembly of organic arrays and properties of organic crystals; basic properties of polymers, including important polymer synthetic methods.

Chem 5302. Interpretation of Organic Spectra. (4 cr, §8302; prereq 3303 or equiv; 4 lect hrs per wk)
Practical application of nuclear magnetic resonance, mass, ultraviolet and infrared spectral analysis to solution of organic structural problems.

Chem 5311. Organic Synthesis I. (4 cr, §8311; prereq 3303 or equiv or #; 3 lect hrs per wk)
Fundamental concepts, reactions, reagents, structural and stereochemical issues, and mechanistic skills necessary for understanding organic chemistry.

Chem 5312. Organic Synthesis II. (4 cr, §8312; prereq 5311 or #; 3 lect hrs per wk)
Topics may include complex carbon skeleton synthesis, asymmetric synthesis, modern studies in organic chemistry.

Chem 5321. Physical Organic Chemistry I. (4 cr, §8321; prereq 5311 or #)
Fundamental concepts; mechanistic tools and methods for understanding and analyzing detailed mechanistic studies in organic chemistry.

Chem 5322. Physical Organic Chemistry II. (4 cr, §8322; prereq 5321 or #)
Topics may include reactive intermediates, gas-phase chemistry, photochemistry, and/or strained-ring chemistry.

Chem 5331. Advanced Organic Chemistry I. (4 cr, §8331; prereq 3303, #; 3 lect hrs per wk)
Topics may include heterocyclic chemistry, natural products chemistry, organic electrochemistry, synthetic applications of organometallic chemistry, solid-state chemistry, polymer chemistry, stereochemistry.

Chem 5332. Advanced Organic Chemistry II. (4 cr, §8332; prereq 3303, #; 3 lect hrs per wk)
Topics may include heterocyclic chemistry, natural products chemistry, organic electrochemistry, synthetic applications of organometallic chemistry, solid-state chemistry, polymer chemistry, stereochemistry.
Chem 5501 (formerly 5520). Introduction to Thermodynamics and Kinetics. (4 cr; §5534; prereq 1052, Math 3251 or equiv, Phys 1106 or Phys 1253 or ¥1253; 4 lect hrs per wk)
Basic thermodynamics with applications to chemical and biological systems. Development of concepts (entropy, Gibbs free energy, chemical potential) needed to understand the equilibrium properties of bulk matter and its physical and chemical changes. Brief introduction to chemical kinetics.

Chem 5502 (formerly 5521). Introduction to Quantum Theory and Spectroscopy. (4 cr; prereq 1052, Math 3251, Phys 1106 or 1253; 4 lect hrs per wk)
Introduction to quantum theory and the electronic structures of atoms and molecules. Spectroscopic techniques widely used by chemists and biochemists, including vibrational (IR, Raman), electronic (UV/vis, photoelectron) and spin (NMR, ESR) spectroscopies.

Chem 5525. Physical Biochemistry: Solution Structure and Interactions of Biological Macromolecules. (4 cr, §BioCMdBc 5525; prereq 2 qtrs physical chemistry, BioC 5331 or equiv; two 1½-hr lect per wk)
Physical chemistry of equilibrium, transport, and scattering phenomena in solution, with application to proteins and nucleic acids. Intermolecular forces, macromolecular dynamics, conformational transitions, binding thermodynamics, methods for determining bioprocessor size and shape, including sedimentation, diffusion, viscosity, electrophoresis, and scattering.

Chem 5526. Physical Biochemistry: Spectroscopic Methods I. (4 cr, §BioCMdBc 5526; prereq 2 qtrs physical chemistry; two 1½-hr lect per wk)
Fundamental spectroscopic principles with emphasis on development of magnetic resonance theory used in the study of biological macromolecules.

Chem 5527. Physical Biochemistry: Spectroscopic Methods II. (4 cr, §BioCMdBc 5527; prereq 2 qtrs physical chemistry; two 1½-hr lect per wk)
Application of optical and magnetic resonance techniques to the study of structure and dynamics in proteins, lipids, nucleic acids, and synthetic analogs.

Chem 5528. Physical Biochemistry: Enzyme Kinetics. (4 cr, §BioCMdBc 5528; prereq 2 qtrs physical chemistry, BioC 5331 or BioCMdBc 8001 or equiv desirable; two 1½-hr lect per wk)
Theory and application of steady-state and transient kinetics to the study of enzymes, enzyme systems, and cellular regulation.

Chem 5529. Protein Structure and Folding. (4 cr, §BioCMdBc 5529; prereq BioC 5331 or equiv, 1 qtr physical chemistry or #; two 1½-hr lect per wk)
Advanced course on protein structure, stability, folding, and molecular modeling. Results from X-ray crystallography, solution thermodynamics, NMR, computer graphics, and protein engineering.

Chem 5533. Quantum Chemistry. (4 cr; prereq 1052, Math 3252 or ¥Math 3252 or Math 3261 or ¥Math 3261, Phys 1253 or ¥Phys 1253; 4 lect hrs per wk)
Principles of quantum mechanics with applications to atomic and molecular structure and to spectroscopy.

Chem 5534. Chemical Thermodynamics. (4 cr, §Chem 5501; prereq upper div IT or CLA Chem major or #, 1052, Math 3251, Phys 1253 or ¥Phys 1253 or Phys 1106 with #; 4 lect hrs per wk)
Principles of thermodynamics with applications to chemical systems.

Chem 5535. Statistical Mechanics and Reaction Kinetics. (4 cr; prereq 5501 or 5534; 4 lect hrs per wk)
Statistical thermodynamics and the kinetic theory of gases with applications to reaction rate theory. Phenomenological kinetics and experimental methods.

Chem 5538. Physical Chemistry Laboratory. (1 cr; prereq 5501 or 5535 or #5535; not open to Chem majors; one 3-hr lab per wk)
Experiments in thermodynamics and reaction kinetics.

Chem 5540. Physical Chemistry Laboratory. (3 cr; prereq 5502 or 5533, Chem majors only; 1 rec, one 4-hr lab per wk)
Lab experiments illustrating principles and methods of thermodynamics, reaction kinetics, and quantum mechanics.

Chem 5610. Principles of Polymer Science. (3 cr, §6810, §MatS 5610; prereq upper div, 3301 or # 3 lect hrs per wk)
Polymer synthesis and physical chemistry: polymerization kinetics and reactors, molecular weight distribution, network formation, macromolecules in solution and their characterization, the glassy and crystalline state, rubber elasticity, flow and viscoelasticity, environmental degradation.

Chem 5702 (formerly 5732). Intermediate Inorganic Chemistry. (4 cr; prereq 3701, 5501 or ¥5501 or ¥5534 or ¥5534; 4 lect hrs per wk)
Emphasis on transition metal chemistry. Advanced topics in main group and materials chemistry.

Chem 5740. Inorganic Chemistry Laboratory. (3 cr; prereq 5702 or ¥5702, Chem majors only; 1 lect, two 4-hr labs per wk)
Lab experiments in inorganic and organometallic chemistry illustrating synthetic and spectroscopic techniques.

Chem 5803. The Chemistry of Industry. (4 cr; prereq Chem sr or grad or #; 3 lect hr per wk)
Industrial and polymer chemistry technology. Relationship of basic properties to industrial utility. Emphasis on economics, social problems, and the industrial environment.

Chem 5970. Directed Study. (Cr ar; prereq any 5xxx Chem course, #)
On- or off-campus learning experiences individually arranged between student and chemistry faculty member, in areas not covered by regular courses.

Chem 5991, 5992, 5993. Selected Topics in Chemistry. (Cr ar; prereq sr, ∆)
Topics of current interest in chemistry. Consult department for details for a particular quarter.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
Chem 8001. Applied Chemical Thermodynamics
Chem 8002. Mechanisms of Chemical Reactions
Chem 8003. Computational Chemistry
COURSE DESCRIPTIONS

Chem 8104. Spectroscopic Methods of Analysis
Chem 8134. Bioanalytical Chemistry
Chem 8135. Mass Spectrometry
Chem 8136. Surface and Thin Film Analysis
Chem 8190. Seminar: Modern Problems in Chemistry Instrumentation and Analysis
Chem 8191. Seminar Presentation: Modern Problems in Chemical Instrumentation and Analysis
Chem 8290 Seminar: Materials Chemistry
Chem 8291. Seminar Presentation: Materials Chemistry
Chem 8302. Interpretation of Organic Spectra
Chem 8311. Organic Synthesis I
Chem 8312. Organic Synthesis II
Chem 8321. Physical Organic Chemistry I
Chem 8322. Physical Organic Chemistry II
Chem 8331. Advanced Organic Chemistry I
Chem 8332. Advanced Organic Chemistry II
Chem 8390. Seminar: Organic Chemistry
Chem 8391. Seminar Presentation: Organic Chemistry
Chem 8401. Bioorganic Chemistry I
Chem 8402. Bioorganic Chemistry II
Chem 8403. Bioorganic Chemistry III
Chem 8404. Bioorganic Chemistry IV
Chem 8512. Chemical Thermodynamics
Chem 8521. Methods of Theoretical Chemistry
Chem 8531-8532-8533. Introductory Quantum Mechanics and Spectroscopy
Chem 8535. Molecular Quantum Mechanics
Chem 8545. Reaction Dynamics
Chem 8547. Elements of Statistical Mechanics
Chem 8548. Advanced Statistical Mechanics
Chem 8560. Seminar: Biological Systems
Chem 8561. Seminar Presentation: Biological Systems
Chem 8590. Seminar: Physical Chemistry
Chem 8591. Seminar Presentation: Physical Chemistry
Chem 8611. Introduction to Polymer Properties
Chem 8612. Advanced Topics in Polymer Science
Chem 8751. Physical Inorganic Chemistry I
Chem 8752. Physical Inorganic Chemistry II
Chem 8756. X-Ray Crystallography
Chem 8761. Organometallic Chemistry
Chem 8762. Chemistry of the Elements
Chem 8765. Bioinorganic Chemistry
Chem 8766. Solid State Chemistry
Chem 8790. Seminar: Modern Problems in Inorganic Chemistry
Chem 8791. Seminar Presentation: Modern Problems in Inorganic Chemistry
Chem 8881, 8882, 8883. M.S. Plan B Project I-II-III
Chem 8990. Research in Chemistry
Chem 8991, 8992, 8993. Special Topics in Chemistry
Chem 8994, 8995, 8996, 8997, 8998. Special Topics in Chemistry

Civil Engineering (CE)

General Courses

CE 1001. Civil Engineering Orientation. (1 cr; S-N only)
Fundamentals of civil engineering practice presented by professional engineers and members of the faculty.

CE 3020. Computer Applications in Civil Engineering I. (4 cr; prereq CE or GeoE students, Math 1261)
Use of PASCAL, graphics, and numerical techniques such as Bisection, Newton-Raphson, Gauss Elimination, Simpson’s Rule, Gauss Quadrature, Predictor-Corrector, and Runge-Kutta for engineering problem solving. Problems drawn from different branches of civil and mineral engineering.

CE 3050. Engineering Intern Work Assignment. (2, 4, or 6 cr; prereq IT student, regis in intern program; S-N only)
Requires submission of two formal written reports, one covering the work completed during the six-month professional assignment and the second involving an in-depth presentation of a related engineering problem.

CE 3051. Engineering Intern Work Assignment. (2, 4, or 6 cr; prereq IT student, regis in intern program; S-N only)
For description, see 3050.

CE 3700. How to Model It. (4 cr, §GeoE 3700; prereq IT student; 4 lect hrs per wk)
Problem formulation, design and construction of models, drawing conclusions from modeling results. Students learn how to use computer-based modeling tools working in small groups on a number of problems from various engineering contexts.
CE 5002. Engineering Economics. (2 cr; prereq IT jr or above, adult spec or grad; 2 lect hrs per wk)
Time value of money; compound amount factors; present worth of uniform and single payments; cost-benefit analysis; net present worth analysis; internal rate of return.

CE 5004. Underground Construction Engineering. (4 cr; prereq upper div IT)
Application of structural and geotechnical techniques to earth-sheltered buildings; construction techniques and problems. Topics include retaining systems, structural loads, drainage systems, waterproofing, site investigation, contracting practices, instrumentation, and heat transfer calculations. Housing, large scale buildings, and mines space.

CE 5010. Senior Design Project. (5 cr; prereq CE sr; 4 lect hrs per wk)
Team participation in formulation and solution of open-ended civil engineering problems from conceptual stage through preliminary planning, public hearings, design, and environmental impact statements to preparation of final plans and specifications, and award of contracts.

CE 5021. Computer Applications in Civil Engineering II. (4 cr; prereq CE or GeoE upper div, 3020, Math 3251, Math 3252)
Introduction to three methods (finite differences, finite elements, boundary elements) for solution of problems in hydrology, structural engineering, geomechanics, transportation, and environmental engineering that reduce to partial differential equations. Methods illustrated in context of practical problems.

CE 5055. Engineering Geostatistics. (4 cr, §GeoE 5437; prereq Stat 3091, CE or GeoE or Geo sr or grad or #)
Problem solving and decision making in civil and geological engineering using applied statistics. Emphasis on spatially correlated data, e.g., geologic site characterization, spatial sampling in environmental engineering, optimal sample design for groundwater contamination assessment.

CE 5097, 5098, 5099. Advanced Design, Analysis, Research, or Tutorial in Civil Engineering. (Cr ar; courses may be taken more than once; prereq approval of faculty adviser)
Special studies in the planning, design, or analysis of complex civil engineering systems. Individual lab research problems, literature studies, and reports supervised by staff members. Studies may be conducted in any discipline within civil engineering and hydraulics including, but not limited to, hydraulics and hydrology, land development, materials, sanitary engineering, soil mechanics, structures, and transportation.

CE 5700. Systems Analysis for Civil Engineers. (4 cr, §GeoE 5700; prereq upper div IT or grad)
Systems analysis and decision making; expert systems; operations research techniques, modeling, and simulation. Applications in civil engineering and related areas.

CE 5703. Project Management. (4 cr; prereq sr standing, IT major)
Construction project management, including project planning, budgeting, scheduling, staffing, task and cost control, and communicating with, motivating, and managing team members.

Surveying and Mapping
CE 3100. Introduction to Surveying and Mapping. (4 cr; prereq IT student, Math 1251; 3 lect, 3 lab hrs per wk)

CE 5102. Site and Route Engineering. (4 cr; prereq IT or grad student, 3100; 3 lect, 2 lab hrs per wk)
Site and route design fundamentals and problems based on topographic map data. Geometric design; grades, horizontal and vertical curves; fitting of design to topography; earthwork, area and volumes. Horizontal and vertical control.

Transportation
CE 3200. Introduction to Transportation Engineering. (4 cr; prereq IT student, Phys 1251)
Application of the physical laws of motion and energy as they relate to calculations of resistances to motion, power, and energy requirements, acceleration-deceleration limits and capacity of various modes of transportation. Estimation of demand for transportation system. Location, design, and operation of transportation facilities.

CE 5200. Geometric Design of Highways. (4 cr; prereq IT or grad student, 3200 or #)
Forecast of traffic volume demand; impact of vehicle type on geometric design; vertical and horizontal alignment; intersection design; highway capacity.

CE 5201. Highway Traffic Characteristics and Operations. (4 cr; prereq IT or grad student, 3200)
Characteristics and measurements of volume, speed, density, and travel time; characteristics of vehicles, and road users; parking characteristics and design of facilities; applications of signs, signals, and markings in traffic control.

CE 5210. Introduction to Transportation Systems Analysis. (4 cr; prereq IT or grad student, 3200, #)
Techniques of analysis and planning for transportation services; demand-supply interactions; evaluating transportation alternatives; travel demand forecasting; integrated model systems; citizen participation in decision making; proposal writing.

CE 5304. Design of Highway and Airport Pavements. (4 cr; prereq IT or grad student, 3300, 5603)
Theories of pavement design, flexible and rigid; equivalent wheel loads. Strength tests and frost action. Design procedures for flexible and rigid pavements.

Geomechanics (Soil Mechanics and Rock Mechanics)
CE 3300. Soil Mechanics. (4 cr; prereq IT student, AEM 3016; 3 lect, 3 lab hrs per wk)

CE 5300. Critical State Soil Mechanics. (4 cr; prereq upper div IT or grad student, 3300)

CE 5302. Applied Rock Mechanics. (4 cr; prereq upper div IT or grad student, 3300; 4 lect hrs per wk) Site investigation; rock mass behavior. Stereographic projections; kinematic analysis of rock slopes. Foundations on rock.

CE 5305. Design of Underground Excavations in Rock. (4 cr, §GeoE 5218; prereq IT or grad IT major; GeoE 5302 or #) Stresses and deformations around underground excavations in rock. Design of linings and support systems. Excavations by boring, drill, and blast. Tunneling under adverse conditions. Materials handling and tunnel ventilation.

CE 5310. Experimental Methods in Material Testing. (4 cr; prereq upper div IT or grad student, 5603; 3 lect, 1 lab hrs per wk) Machine stiffness; closed-loop testing. Small-strain theory. Measurement of deformation; strain gages, LVDTs, accelerometers, and related circuits. Material behavior; direct and indirect tests.

Water Resources, Hydraulic Engineering, and Hydrology

CE 3400. Fluid Mechanics. (4 cr; prereq IT student or WPS major, Math 3261, AEM 1015 or 3016; 3 lect, 3 lab hrs per wk) Fluid statics and dynamics for liquids and gases. Kinematics of fluid flow, viscous effects, and introduction to incompressible and compressible duct flow. Boundary layers, lift and drag, fluid measurements.

CE 5401. Water Resources Engineering. (4 cr; prereq IT or grad student, 3400 or #; 3 lect, 3 lab hrs per wk) Introduction to water resources engineering including flow in conduits, pumps, open channels, and culverts; introduction to flow measurements, hydraulic structures and systems approach to water resources engineering.

CE 5402. Computational Hydraulics. (4 cr; prereq IT or grad student, 5401, CSci 3101 or #; 3 lect, 3 lab hrs per wk) Computer applications in hydraulic engineering with emphasis on iteration techniques and finite increment methods applied to open channel flow profile analysis: analysis of flow through spillways, bridge waterways, culverts, and similar structures.

CE 5403. Hydraulic Structures. (4 cr; prereq IT or grad student, 5401 or #) Hydraulic design procedures for such structures as culverts, dams, spillways, outlet works; river control works; drop structures, water intakes, bridge crossings, pipeline crossings.

CE 5405. Hydrology and Hydrologic Design. (4 cr; prereq IT or grad student or #; 3 lect, 3 lab hrs per wk) Hydrologic cycle, precipitation, evaporation, infiltration, runoff analysis, flood routing, statistical procedures in hydrology, urban hydrology, introduction to mathematical models of medium and large watersheds, application of hydrology to design of outlet works and flow control structures.

CE 5410. Open Channel Hydraulics. (4 cr; prereq IT or grad student, 3400, 5401 or #; 3 lect, 2 rec hrs per wk) Mechanics of flow in open channels including gradually varied, spatially varied, and rapidly varied flow; unsteady flow (waves and surges) and flow in alluvial channels.


CE 5435. Intermediate Fluid Mechanics With Applications. (4 cr; prereq IT or grad student, 3400) Basic laws and equations of fluid flow, mass transport, and heat transport, with exact and approximate solutions. Derivation of similarity parameters from basic equations. Two- and three-dimensional potential flow.

Environmental Engineering

CE 3500. Principles of Environmental Engineering. (4 cr; prereq IT student, Chem 1052, Phys 1253; 4 lect hrs per wk) Hydrologic, ecologic, chemical, and microbiological concepts needed to understand environmental problems and analyze and model pollutant behavior; pollution control devices and systems; pollution prevention; risk-based approaches to environmental decision making.

CE 5500. Analysis and Design of Water Supply Systems. (4 cr; prereq IT or grad student, 3400, 5401 or #) Planning and engineering design considerations in developing water supply systems for urban centers. Supply quality, storage, treatment, distribution, and cost analysis.

CE 5501. Analysis and Design of Wastewater Systems. (4 cr; prereq IT or grad student, Chem 1052, 3400 or #) Planning and engineering design considerations in developing waste disposal systems for urban centers. Volumes and quality of waste streams, treatment and ultimate disposal of domestic and industrial wastewaters, and storm water runoff. Environmental effects, cost, and political aspects of ultimate disposal.

CE 5504. Mass Transport With Environmental Applications. (4 cr; prereq IT or grad student, 3400 or #) Principles of reactor design for water and wastewater treatment and pollutant transport in the environment.

CE 5505. Water Quality Engineering. (4 cr; prereq IT or grad student, 5506 or #) Chemical, physical, and biological properties of natural waters; water quality criteria, standards, and legislation; mathematical modeling to predict fate/effects of oxygen-demanding pollutants, nutrients, and refractory organic contaminants on receiving waters.
CE 5506. Environmental Water Chemistry. (4 cr; prereq IT or grad student, Chem 1052 or #; 3 lect, 1 rec hrs per wk)
Composition of natural waters and wastewater; chemical processes affecting distribution of chemical species, including pollutants, in water; methods to evaluate fate of organic pollutants.

CE 5507. Environmental Engineering Laboratory. (4 cr; prereq upper div IT or grad student, 5500 or 5501, 5506 or #; 3 lect, 3 lab hrs per wk)
Methods of sampling natural water and wastewater; techniques for the chemical, biological, and physical characterization of samples, including nutrients, indicator organisms, BOD, major and minor ions, natural synthetic organic matter.

CE 5510. Solid and Hazardous Waste Management. (4 cr; prereq IT or grad student, Chem 1052 or #)
Solid and hazardous waste characterization; regulatory legislation; waste minimization; resource recovery; chemical, physical, and biological treatment; thermal processes; disposal practices. Analysis and design of systems for treatment and disposal.

CE 5512. Solid and Hazardous Waste Processing I. (4 cr; prereq upper div IT or grad student, 5510 or #; 4 lect hrs per wk)
Application of physical and chemical principles to unit operations and processes for recovering and recycling solid wastes. Remediation and pollution prevention methodologies on solid and hazardous wastes from manufacturing industries, municipal waste treatment plants, electric power utilities, and the mining industry. Student presentations and reports.

CE 5513. Solid and Hazardous Waste Processing II. (4 cr; prereq upper div IT or grad student, 5512 or #; 4 lect hrs per wk)
Continuation of 5512. Pyro-processing and high-temperature treatment approaches; chemistry of high-temperature systems; thermal incineration principles; encapsulation of radioactive waste, developing technologies in high-temperature treatment of hazardous wastes.

CE 5515. Water and Wastewater Microbiology. (4 cr; prereq Chem 1005, Math 1052)
Analysis of role of microbes in environmental degradation and pollution control. Organism growth and selection in wastewater treatment systems. Pathogens in receiving waters and water supplies. Microbial indicators of water quality.

CE 5540. Analysis of Groundwater Soil Pollution Abatement Technology. (4 cr; prereq IT or grad, 5401, 5501 or #)

CE 5580. Introduction to Environmental Law for Engineers. (4 cr; prereq upper div IT or grad student or #; 4 lect hrs per wk)
Environmental regulatory law relevant to civil and environmental engineering; specific provisions of federal statutory and regulatory laws such as NEPA, CWA, RCRA, CAA, and CERCLA.

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**Structural Engineering**

CE 3600-3601-3602. Structural Design for Architects. (4 cr per qtr; prereq adult spec or AEM 3092, 3093; 4 lect, 1 rec hrs per wk)
Behavior, analysis, design, and construction of structural systems and members in steel, reinforced concrete, timber, masonry, and plastics.

CE 5600. Linear Structural Systems. (4 cr; prereq IT or grad student, AEM 3016)
Analysis of determinate and indeterminate linear structural systems; analysis of trusses and frames through virtual work, moment distribution, energy methods, and slope-deflection equations. Influence lines. Approximate methods of analysis. Design considerations.

CE 5601. Matrix Analysis of Structures. (4 cr; prereq IT or grad student, 5600)
Analysis of linear structural systems by matrix methods based on the structural stiffness approach. Introduction to the finite element method and to computerized analysis of structural systems.

CE 5602. Topics in Structural Mechanics. (4 cr; prereq upper div IT or grad student, 5600, AEM 3036)
Introduction to theory of elasticity; theory of vibration for single-degree-of-freedom structures; energy methods of approximate structural analysis; torsion of beams; numerical calculation of buckling heads of bars and plates.

CE 5603. Introduction to Construction Materials. (4 cr; prereq upper div IT, AEM 3016)
Basic concepts of behavior mechanisms of materials such as concretes, metals, and woods.

CE 5610. Design of Metal Structures: Introduction. (4 cr; prereq upper div IT or grad student, 5600, 5601)
Loads on civil structures. Load factor and working stress philosophies of design. Design of tension, compression, and flexural members and their connections. Codes, properties of structural metals.

CE 5611. Design of Reinforced Concrete Structures. (4 cr; prereq upper div IT or grad student, 5600, 5603)
Principles of strength and serviceability in reinforced concrete structural design. Strength analysis, design of beams, joists, one-way slabs for flexure and shear. Anchorage, development, splicing of reinforcement. Stresses at service, deflections, cracking, long-term effects. Introduction to design of columns, continuity; simple footings.

CE 5612. Design of Metal Structures: Intermediate. (4 cr; prereq IT or grad student, 5610)
Design of complete metal structures; plate girder bridges, industrial buildings, multistory structural frames.

CE 5613. Intermediate Reinforced Concrete Design. (4 cr; prereq IT or grad student, 5611; 4 lect hrs per wk)
CE 5615. Prestressed Concrete. (4 cr; prereq IT or grad student; 5611, 5612, 5613 recommended; 4 lect hrs per wk) Types and properties of high-strength concretes and steels for prestressed concretes. Design of pretensioned and post-tensioned members. Post-tensioning systems. Precast, prestressed building systems, floors, roofs, bridges. Continuity in precast, prestressed systems. Design of connections.

CE 5617. Design of Masonry Structures. (4 cr; prereq IT or grad student, 5600 or #; 4 lect hrs per wk) Masonry materials and their production, mortars and grouts, design of nonreinforced and reinforced masonry structural systems, walls, columns, lintels, arches. Codes and specifications, testing, and inspection.

Construction Materials
CE 5701. Bituminous Materials I. (4 cr; prereq upper div IT or grad student, 5603; 3 lect, 3 lab hrs per wk) Physical and chemical properties and characteristics of bituminous binders and aggregates. Properties and design of bituminous mixtures and surface treatments.

CE 5702. Components, Properties, and Design of Portland Cement Concrete. (4 cr; prereq upper div IT or grad student, 5603; 3 lect, 3 lab hrs per wk) Physical and chemical properties and characteristics of portland cement, aggregates, and admixtures. Properties and design of concrete mixtures.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
CE 8022. Numerical Methods for Free and Moving Boundary Problems
CE 8097-8098-8099. Civil Engineering Research
CE 8200. Theory of Traffic Flow
CE 8201. Urban Traffic Operations
CE 8210. Modeling Consumer Choices in Transportation
CE 8211. Travel Demand Forecasting
CE 8212. Automatic Incident Detection
CE 8214. Transportation Systems Dynamics and Control
CE 8302. Soil/Rock Plasticity and Limit Analysis
CE 8321. Mechanics of Granular Media
CE 8322. Storage and Flow of Granular Material
CE 8360. Engineering Model Fitting
CE 8401. Introduction to Environmental Boundary Layer Theory
CE 8402. Introduction to the Theory and Measurement of Turbulent Flows
CE 8407. Stochastic Hydrology
CE 8408. Special Topics in Hydrology

CE 8413. Mechanics of Sediment Transport
CE 8415. Hydropower Development
CE 8418. Computational Hydrodynamics I
CE 8419. Computational Hydrodynamics II
CE 8425. Advanced Groundwater Mechanics I
CE 8426 Advanced Groundwater Mechanics II
CE 8430. Lake and Reservoir Hydrodynamics
CE 8435. Special Topics in Hydrodynamic Theory
CE 8440. Flow Effects on Structures
CE 8500. Physical and Chemical Processes for Water and Wastewater Treatment I
CE 8501. Physical and Chemical Processes for Water and Wastewater Treatment II
CE 8502. Biological and Chemical Processes for Wastewater Treatment
CE 8505, 8506. Aquatic Chemistry for Environmental Engineers
CE 8507. Environmental Processing of Organic Materials
CE 8540. Interfacial Mass Transfer With Environmental Applications
CE 8550. Analysis and Modeling of Aquatic Environments
CE 8551. Seminar on Models of Aquatic Environments
CE 8605. The Finite Element Method in Civil Engineering
CE 8606. Approximate Methods of Structural Analysis
CE 8608. Advanced Theory of Structures
CE 8609. Principles of Structural Stability
CE 8610. Shell Structures
CE 8611. Plate Structures
CE 8612. Plastic Design of Steel Structures
CE 8616. Nonlinear Structural Systems
CE 8618. Reliability in Structural Engineering
CE 8620-8621. Structural Dynamics I-II
CE 8625. Behavior of Reinforced Concrete Structures I
CE 8626. Behavior of Reinforced Concrete Structures II
CE 8690. Structures: Special Topics
CE 8697-8698-8699. Seminar: Structures
Computer Science (CSci)

CSci 1001. Introduction to Computers for Non-Computer Science Majors. (4 cr; no degree cr for IT students)
History and societal impact of computers; legal and ethical issues in computer usage; basic computer organization; concept of an algorithm; flowcharting; understanding of and hands-on experience with software packages ranging from editing and word processing to symbolic mathematics.

CSci 3101. Introduction to Computer Applications for Scientists and Engineers. (4 cr; prereq first-qtr calculus; informal lab)
Algorithm development and principles of computer programming using FORTRAN, emphasizing numerical methods for science and engineering applications. Integral open lab.

CSci 3113. Introduction to Programming in C. (4 cr; prereq precalculus or #; not for cr after taking 3121 or 3321 or 5113)
Computer programming in the procedural paradigm. Students use the C language to write several programs that illustrate flow control, basic data types (array, record, pointer), and program structuring. Prepares students for more advanced courses in data structures and algorithms.

CSci 3311. Discrete Structures of Computer Science. (4 cr, §3400; prereq 3317, 3321)
Mathematical techniques and structures in computer science. Formal logic, elementary combinatorics, induction, recurrences, relations and graphs.

CSci 3316. Structure of Computer Programming I. (4 cr, §3106; prereq 1 qtr calculus or #)
Different programming paradigms as a formal way of expressing computer algorithms and data. Procedures, recursion, and iteration as algorithmic development techniques. Use of abstraction and modularity. Scheme language used to illustrate ideas and lab problems.

CSci 3317. Structure of Computer Programming II. (4 cr; prereq 3316)
Advanced programming paradigms. Object-oriented programming, logic programming, and pattern matching illustrated with examples. Generic operators, local variables, and objects as ways of encapsulating different conceptual parts of a program. Scheme language used to illustrate ideas and lab problems.

CSci 3321. Algorithms and Data Structures I. (4 cr, §3105, §3121; prereq knowledge of C or 3113 or #)
Fundamental data structures with some of the rudimentary computer algorithms. Students implement these data structures and their operations as abstract data types. Study of C++ with emphasis on implementation of data types and control structures.

CSci 3322. Algorithms and Data Structures II. (4 cr, §5121; prereq 3311, 3321)
Fundamental paradigms for algorithm design with the supporting data structures. Complexity, correctness analysis, and lower bound theory. Implementation of selected algorithms and data structures using C++.

CSci 3327. Introduction to the Organization of Computer Systems. (4 cr, §3107, §5101; prereq 3316 or 3321 or #)
Organization of hardware and software systems that support computer programming and program execution. Symbolic assembly language used to study the mapping of application programs and data into the underlying hardware. Ideas illustrated in assembly language programs (currently Motorola 680x0).

CSci 3977. Industrial Assignment. (2 cr; prereq CSci major, regis in CSci co-op program or # may be repeated for cr up to 4 times)
Industrial work assignment in computer science co-op program involving advanced computing technology, reviewed by faculty. Grade based on student’s final written report covering the quarter’s work assignment.

Developments in the last century: factors affecting evolution of hardware and software, growth of the industry and its relation to other business areas, changing relationships resulting from new data-gathering and analysis techniques.

CSci 5101. Introduction to the Organization of Computer Systems. (4 cr, §3107, §3327; prereq 3316 or 3321, non-CSci major or #; informal lab)
Organization of hardware and software systems that support computer programming and program execution. Symbolic assembly language used to study the mapping of application programs and data into the underlying hardware. Ideas illustrated in assembly language programs (currently Motorola 680x0).

CSci 5102. Introduction to Systems Programming. (4 cr; prereq 3327 or 5101 or #; informal lab; does not carry grad cr for CSci majors)
User-level programming view of operating system functions. Introduction to UNIX systems programming. Use of system calls, relationships between C library functions and systems calls, file systems, process management functions, input-output, signal handling, use of pipes and sockets, shell programming.

CSci 5103. Introduction to Operating Systems. (4 cr; §5502; prereq 3322, 5102, 5201 or #; informal lab)
Concepts used in operating system designs and implementations. Relationships between operating system structures and underlying machine architectures. UNIX implementation mechanisms presented as examples.

CSci 5104. System Simulation: Languages and Techniques. (4 cr; prereq 3327 or 5101, Stat 3091 or #; informal lab)
Methodologies relevant to system modeling and simulation. Application of stochastic processes, Markov chains, and queuing theory to developing system models and simulation experiments. Data collection and statistical analysis of output. Fundamentals of discrete event-based simulations using digital computers. Discussion of simulation languages, both process- and event-oriented, including SIMULA and SIMPAS. Applications of these techniques to job shops, operations research, and modeling of computer and communications systems.
CSci 5106. Structure of Higher-Level Languages. (4 cr; prereq 3317, 3321, 3327, or # informal lab; does not carry grad cr for CSci majors)
Motivation, syntax and semantics, imperative languages (e.g., Ada, C), type system, control structures, procedures, activation record model, exception handlers; encapsulation, parameterization; functional languages (e.g., Lisp, Scheme, ML or FP); object-oriented languages (e.g., Smalltalk, C++ or CLOS); trends (e.g., concurrent model).

CSci 5107. Computer Graphics I. (4 cr; prereq 3322, 3327 or # informal lab)
Students do extensive programming and learn theoretical underpinnings of computer graphics. General graphics issues, user interface issues, 2D graphics, introduction to 3D graphics (3D pipeline, shading and hidden surface removal, ray tracing).

CSci 5110. User Interface Design, Implementation, and Evaluation. (4 cr; prereq 3322, 3327 or # informal lab)
Task-centered approaches to user interface design. Students work in groups on a course-long project that includes designing, prototyping, implementing, and evaluating an application interface. User testing and nonuser walk-through and heuristic techniques.

CSci 5111. GUI Toolkits and Their Implementation. (4 cr; prereq 5107 or 5110 or # informal lab)
Structure and design of user interface toolkits and frameworks. Includes window system protocols, toolkit design, event processing, data management and constraints, geometry management, resource management, and other features of advanced interface development toolkits. Students complete a project in which they implement a toolkit extension or widget.

CSci 5113. Introduction to Object-Oriented Programming Using C++. (4 cr, §3121, §3321, §3322; prereq background in C programming equiv to 3113; no grad cr for CSci majors)
For students who already know how to program in C. Inheritance, including polymorphism and multiple inheritance. Container classes and iterators. Operator overloading, user-defined implicit conversions, constructors, destructors, and templates.

CSci 5117. Computer Graphics II. (4 cr; prereq 5107 or # informal lab)
Spline curves and surfaces, and other advanced modeling techniques, solid modeling, color theory, advanced shading algorithms, advanced ray tracing, radiosity, introduction to scientific visualization.

CSci 5121. Algorithms and Data Structures II. (4 cr, §3322; prereq 3311 or #)
Fundamental paradigms for algorithm design with the supporting data structures. Complexity, correctness analysis, and lower bound theory. Implementation of selected algorithms and data structures using C++.

CSci 5131. Internet Programming. (4 cr; prereq 5106 or 5211; 5180, 5702 recommended)
Java programming, concurrent collaboration, workflow, distributed database, security, collaborative computing, object-oriented architecture and design, network publishing, messaging architecture, distributed object computing, and intranet. Programming exercises.

CSci 5151. Introduction to Parallel Computing. (4 cr; prereq 3121 or 3322 or #)

CSci 5161. Introduction to Compilers. (4 cr, §5504; prereq 5106 or # informal lab)
Techniques for implementing programming languages. Compiler front end, recognizing syntactic structures, generating internal representations. Symbol table manipulation and type checking.

CSci 5180. Software Engineering I. (4 cr; prereq 5106 or # informal lab)
Software life cycle, requirement acquisition, specification, design, coding, and testing. Criteria for requirement acquisition, object-oriented analysis and modeling, structures analysis, process description. Techniques for specification verification and validation, completeness and consistency, and multilevel checking. Formal analysis of semiformal specifications. Object-oriented design techniques and patterns. Current software development and application environments. Software prototyping, maintenance, and application issues. Students participate in a group project to develop an application from user requirements.

CSci 5181. Software Engineering II. (5 cr; prereq 5180; scheduled lab)
Requirement analysis. Project planning and management. Design reviews, software testing, validation strategies. Maintenance. Lab with group projects, 12 hours per week project work outside class. Selected projects on the process of systems development, from requirements analysis through maintenance. Student groups will specify, design, implement, and test partial software systems. Emphasis on application of general software development methods and principles from 5180, rather than on specific systems.

CSci 5199. Problems in Languages and Systems. (1-4 cr [may be repeated for cr]; prereq #)
Special courses or individual study arranged with faculty member.

CSci 5201. Computer Architecture. (4 cr; prereq 3311, 3327 or # informal lab)
Elementary computer architecture, gates and digital logic, register transfers and micro-operations, processor studies of existing systems.

CSci 5211. Data Communications and Computer Networks. (4 cr; prereq 5102 or # informal lab)
Network classification and services. Hardware components: multiplexers, concentrators, communications media. Network protocols and architectures. Research areas.

CSci 5212. Network Programming. (2 cr; prereq 5102, §5211 or # informal lab; 5211; no grad cr for CSci majors)
Network and distributed programming concepts using C++ and UNIX, including TCP/IP, sockets, and RPC applications.

CSci 5221. Advanced Computer Networks and Its Applications. (4 cr; prereq 5211 or #)
Design, maintenance, and use of high-speed networks and their impact on society. Emphasis on new protocols, such as FDDI-II, Frame-Relay, ATM. Characteristics of hardware, protocols, and applications, such as high-performance distributed computing and multimedia.
CSci 5222. Network Operations and Administration. (4 cr; prereq 5211 or #; no grad cr for CSci majors)

CSci 5280. Computer-Aided Design. (4 cr; prereq 3311 or #; informal lab)
CAD for digital systems with emphasis on VLSI. Hardware description languages: synthesis, simulation, test generation.

CSci 5281. Computer-Aided Design of VLSI. (4 cr; prereq 3311 or #; informal lab)
CAD for digital systems with emphasis on VLSI. Physical design: partitioning, placement and routing, design and electrical rule checks. Inherent complexity of algorithms. Analysis of best known algorithms.

CSci 5299. Problems in Machine Design. (1-4 cr [may be repeated for cr]; prereq #)
Special courses or individual study arranged with faculty member.

CSci 5301. Numerical Computation. (4 cr; prereq Math 3261, knowledge of a programming language or #)

CSci 5302. Analysis of Numerical Algorithms. (4 cr; prereq 5301 or #)

CSci 5304. Computational Aspects of Matrix Theory. (4 cr; prereq 5302 or #; informal lab)

CSci 5305. Numerical Methods for Ordinary Differential Equations. (4 cr; prereq 5302 or #; informal lab)

CSci 5306. Numerical Methods for Partial Differential Equations. (4 cr; prereq 5302, differential equations or advanced calculus or #)

CSci 5320. Introduction to Linear Programming. (4 cr, §5001; prereq 5301 or #; informal lab)
Basic solutions to linear systems; inequalities; convex polyhedral sets; linear programming formulation and optimality conditions; theoretical and computational aspects of simplex algorithm; postoptimality analysis; duality. Revised simplex and numerically stable methods, upper-bounded problems; commercially available LP systems; methods for large, sparse systems. Interior methods for LP.

CSci 5339. Problems in Numerical Analysis. (1-4 cr [may be repeated for cr]; prereq #)
Special courses or individual study arranged with faculty member.

CSci 5400. Introduction to Automata Theory. (4 cr; prereq 3311 or #)
Turing machines, computable functions, unsolvability of the halting problem, recursive functions. Finite state models; equivalence, minimization, properties, decision questions, characterizations. Regular expressions. Survey of other automata.

CSci 5421. Introduction to Algorithm Design. (4 cr, §8401; prereq 3322, 5121 or #; informal lab)
Divide-and-conquer, dynamic programming, the greedy method, matroids, backtracking and branch-and-bound, basic graph algorithms, techniques for geometric problems, string matching.

CSci 5422. Advanced Data Structures. (4 cr, §5122; prereq 3322 or 5121 or #)
Advanced techniques for representing and manipulating data efficiently and analyzing the performance of these methods. Priority queues, balanced search trees, multidimensional searching structures, amortized complexity and its applications to data structure design, persistent data structures, data structures for secondary storage.

CSci 5442. Introduction to Computational Geometry. (4 cr; prereq 5421 or #)
Techniques for designing and analyzing geometric algorithms. Geometric problems that occur naturally in various applications such as computer graphics, solid modeling, CSD, robotics, manufacturing, and vision. “Pure” and “applied” aspects of geometric computation.

CSci 5499. Problems in Computational Theory or Logic. (1-4 cr [may be repeated for cr]; prereq #)
Special courses or individual study arranged with faculty member.

CSci 5511. Artificial Intelligence I. (4 cr; prereq 3322 or #; informal lab)

CSci 5512. Artificial Intelligence II. (4 cr; prereq 5511 or #; informal lab)
CSci 5521. **Pattern Recognition.** (4 cr; prereq 5301, Stat 3091 or #; informal lab)

CSci 5531. **Artificial Intelligence Programming Techniques.** (4 cr; prereq 5511 or #; informal lab)
Languages and programming techniques for problems in artificial intelligence. Lisp and Prolog. Production system and frame-based languages. High-level tools. Implementation of knowledge representation structures and inference operations. Applications in expert systems.

CSci 5551. **Introduction to Intelligent Robotic Systems.** (4 cr; prereq 5511 or #)
Fundamentals of operations of a robot manipulator. Overview of sensing techniques and introduction to their basic principles. Real-time programming issues as applied to the control of a robot. Robot programming and planning.

CSci 5561. **Computer Vision.** (4 cr; prereq 5511 or #)

CSci 5571. **Expert Systems.** (4 cr; prereq 5511 or #)
Introduction to expert systems. Aspects of artificial intelligence representations and inferencing mechanisms as they apply to expert systems. Students develop a small expert system.

CSci 5599. **Problems: Artificial Intelligence.** (1-4 cr [may be repeated for cr]; prereq #)
Special courses or individual study arranged with faculty member.

CSci 5702. **The Principles of Database Systems.** (4 cr; prereq 3322 or #; informal lab)

CSci 5703. **Database System Design.** (4 cr; prereq 5702 or #; informal lab)
Application of database concepts in the design and development of database systems and database applications. Design of current commercial and research-oriented database systems. Techniques of using database systems for applications.

CSci 5705. **Object-Oriented Databases.** (4 cr; prereq 5702 or #)
Applications and motivation; extended relational, object-relational, and object-oriented data models; object identifier, types and constructors; versions and schema evolution; query language (e.g. recursion, path expressions); object indices, buffer management and other implementation issues; triggers, rules, complex objects, case studies.

CSci 5799. **Problems in Information Science.** (1-4 cr [may be repeated for cr]; prereq #)
Special course or individual study arranged with faculty member.

CSci 5863. **Computer Systems Performance Analysis.** (4 cr; EE 5863; prereq 5201 or EE 5858, grad IT major or #)
Tools and techniques for measuring and analyzing computer hardware, software, and system performance. Benchmark programs, measurement tools, performance metrics. Presenting data, summarizing measured data, comparing system performance. Deterministic and probabilistic simulation techniques, random number generation and testing. Bottleneck analysis.

CSci 5990. **Advanced Project Laboratory.** (4 cr; prereq upper div CSci student, 5102, # no grad cr for CSci majors; may be repeated for cr)
Formulating and solving an open-ended problem. Projects span a variety of subjects and applications and include design, implementation, interface, documentation, and testing. Teamwork strongly encouraged. Projects arranged with computer science faculty.

**For Graduate Students Only**
(For descriptions, see Graduate School Bulletin)

CSci 8101. **Advanced Operating Systems**
CSci 8102. **Operating Systems Theory**
CSci 8103. **Distributed and Parallel Programming**
CSci 8110. **Human-Computer Interaction and UI Technology**
CSci 8161. **Advanced Compiler Techniques**
CSci 8163. **Compiler Techniques for Parallel Architectures**
CSci 8180. **Advanced Software Engineering**
CSci 8199. **Seminar: Languages and Systems**
CSci 8203. **Advanced Computer Architecture**
CSci 8205. **Parallel Computer Organization**
CSci 8221. **Special Research Topics in Computer Networking**
CSci 8299. **Special Research Topics in Computer Networking**
CSci 8305. **Seminar: Machine Design**
CSci 8305. **Seminar: Machine Design**
CSci 8314. **Iterative Methods for Linear Systems**
CSci 8320. **Numerical Solution of Linear Least Squares Problems**
CSci 8330. **Parallel Methods for Numerical Optimization**
CSci 8350. **Advanced Parallel Numerical Methods**
CSci 8360. **Numerical Linear Algebra in Dynamical Systems**
CSci 8399. **Seminar: Numerical Analysis**
CSci 8403-8404. **Theory of Computation**
CSci 8421. **Advanced Algorithm Design**
CSci 8499. Seminar: Computational Theory and Logic
CSci 8521. Neurocomputing and Neural Networks
CSci 8551. Artificial Intelligence Techniques in Robotics
CSci 8561. Readings in Computational Vision
CSci 8571. Readings in Expert Systems
CSci 8581. Readings in Parallel Symbolic Computing
CSci 8599. Seminar: Artificial Intelligence
CSci 8701. Overview of Database Research
CSci 8703. Distributed and Parallel Databases
CSci 8705. Scientific Databases and Applications
CSci 8799. Seminar: Information Science
CSci 8899. Colloquium: Computer Science

Electrical Engineering (EE)

EE 1000. Introduction to Electrical Engineering. (1 cr; prereq lower div IT or Δ; S-N only)
Introduction to electrical engineering presented by practicing engineers and members of the faculty.

EE 1400. Circuits Laboratory. (1 cr; prereq IT student, 3009 or §3009)
Lab to accompany 3009 and 3010.

EE 3005. Electronic Circuits and Systems. (4 cr; not for EE majors; prereq IT student, 3009)

EE 3006. Circuits and Electronics Laboratory. (1 cr; not for EE majors; prereq IT student, 3005 or §3005)

EE 3009. Linear Circuits I. (4 cr; prereq IT student, Math 3261, Phys 1253)

EE 3010. Linear Circuits II. (4 cr; prereq IT student, at least C grade in 3009, Math 3261, Phys 1253)

EE 3011. Signal Analysis. (4 cr; prereq upper div EE major, 3010)

EE 3012. System Design. (4 cr; prereq upper div EE major, 3011)

EE 3021. Probability in Engineering Systems. (4 cr; prereq upper div EE major, 3011)

EE 3061. Analog Electronics. (4 cr; prereq upper div IT, 3010, §3400)
Small signal models for the BJT and FET. Elementary amplifiers. Differential and operational amplifiers; applications.

EE 3062. Analog and Digital Electronics. (4 cr; prereq upper div IT, 3061, 3351, §3401)
Stability and feedback amplifiers, operational amplifier structures; implementation of digital circuits with bipolar and field-effect transistors; application to inverters, gates, flip-flops, logic arrays, and storage elements.

EE 3063. Semiconductor Devices (formerly 3060). (4 cr; prereq upper div IT, 3010 or §3010, Phys 3501)
Elementary semiconductor physics; physical description of p-n junction diodes, bipolar junction transistors, and field-effect transistors.

EE 3110. Electric and Magnetic Fields. (4 cr; prereq upper div IT, Phys 3501, Math 3252)
Field properties of electricity and magnetism. Interaction with dielectric and magnetic materials.

EE 3111. Electromagnetic Waves. (4 cr; prereq upper div EE, 3110)

EE 3351. Introduction to Logic Design. (4 cr; prereq IT soph or jr or sr)
Boolean algebra and logic gates. Combinational logic: simplification and design examples. Sequential logic and design of synchronous sequential logic systems. Integral lab.

EE 3352. Introduction to Microprocessors. (4 cr; prereq IT soph, CSci 3113)

EE 3400-3401-3402. Junior Electrical Engineering Laboratory. (2 cr per qtr; prereq EE major, 1400, §3061 for 3400, §3062 for 3401, §3063 for 3402)
Experiments in circuits and electronics. A team design problem for 3402.

EE 3470-3471. Summer Engineering Employment. (1-3 cr per qtr; prereq completion of 2nd- or 3rd-yr work, declaration of intention before end of spring qtr, regis in fall qtr, #)
Summer work in an engineering field; minimum of 360 hours per summer. Requires a technical report.

EE 3476-3477. Industrial Assignment I-II. (2 cr; prereq regis in EE co-op program)
Industrial work assignment in electrical engineering co-op program. Grade based on student’s formal written report covering quarter’s work assignment but deferred until completion of EE 5478.
**Course Descriptions**

EE 5002. Digital Signal Processing. (3 cr; prereq upper div EE or grad IT major, 3012 or #)
General concepts of signal processing; discrete-time systems and digital filters.

EE 5053. Design of Digital Circuits. (3 cr; prereq upper div EE or grad IT major, 3062 or #)
Design of modern digital integrated circuits at subsystem level. Nonlinear device models used to predict system performance. Comparison of performance and topology of various logic families including TTL, MOS, CMOS, FL, and ECL.

EE 5055. Instrumentation and Control Electronics. (4 cr; prereq upper div EE or grad IT major, 3012 or $3012, 3062 or #)
Characteristics of operational amplifiers; applications of operational amplifiers including A-D and D-A converters; compensation of operational amplifiers; power amplifiers; semiconductor controlled rectifiers, applications; linear and switching voltage regulators.

EE 5056. Electronic Circuits Laboratory. (1 cr; prereq IT student or grad IT major, 3402 or $33402, 5055)

EE 5090. Digital Circuit Design Laboratory. (1 cr; prereq 3402 or $33402, 5053)

EE 5151. Materials and Devices I. (4 cr; prereq IT student or grad IT major, 3062, 3111, Phys 3501 or #)
Fundamental electronic properties of materials with emphasis on semiconductors. Carrier transport and statistics. Diodes, BJT’s, and lasers.

EE 5161. Materials and Devices II. (4 cr; prereq 5151 or #)
Introduction to fundamental physical properties of structures, dielectric, and magnetic systems. Metal semiconductor contacts, MOS structures, fiber optics, superconductors.

EE 5162. Solid-State Transducers. (3 cr; prereq IT student or grad IT major, 3060, 3111, Phys 3501 or #)
Design and operation of solid-state devices used for transducing physical and chemical signals.

EE 5202. Analog Communication. (3 cr; prereq upper div EE or grad IT major, 3012, 3021 or #)
Selected topics in analog communication systems: amplitude and frequency modulation; spectral analysis and effect of noise in modulation systems; detection.

EE 5203. Introduction to Digital Communication. (3 cr; prereq upper div EE or grad IT major, 3012, 5202, 3021 or #)

EE 5240. Analog Communications Laboratory. (1 cr; prereq EE sr or grad IT major, 3402 or $33402, 5202)

EE 5241. Digital Communications Laboratory. (1 cr; prereq EE sr or grad IT major, 3402 or $33402, 5203)

EE 5253. Linear Control Systems. (3 cr; prereq upper div EE or grad IT major, 3012 or #)

EE 5255. Digital Control Systems. (3 cr; prereq upper div EE or grad IT major, 3351, 3352 or equiv, 5002 or $5002, 5253 or #)
Time- and frequency-domain analysis of discrete-time and digital control systems. Data conversion and interfacing. Digital computers as control system components. Software and hardware considerations in digital control system design.

EE 5290. Digital Control Systems Laboratory. (1 cr; prereq upper div EE, 5291, 5255)

EE 5291. Linear Control Systems Laboratory. (1 cr; prereq EE sr or grad IT major, 3402 or $33402, 5253)

EE 5300. Electromechanics. (4 cr; upper div EE or grad IT major, 3011, 3110)
Principles of electromechanical energy conversion with applications to actuators, transducers, and rotating machines. Performance characteristics derived from analytical models of AC and DC machines.

EE 5310. Electric Power Systems. (4 cr; prereq IT student or grad IT major, 3402 or $33402, 5300 or #)

EE 5315. Electromechanics in Robotics. (3 cr; prereq upper div EE, 3012, 5300 or #)

EE 5322. Electromechanical Processes and Devices. (4 cr; prereq IT student or grad IT major, 3402 or $33402, 5300 or #)

EE 5355. Microprocessor Interfacing and System Design. (4 cr; prereq upper div EE or grad IT major, 3351, 3352, 3402 or $33402 or #)

EE 5358. Digital Design With Programmable Logic. (4 cr; prereq EE upper div or grad IT major or adult spec, 3351, 3352)

EE 5450. Senior Design Project. (2 cr [may be repeated for cr]; prereq EE sr, 3012, 3062, 3110, 3351, 3352, 3402)
Team participation in formulating and solving open-ended design problems. Oral and written presentations.
EE 5470. Directed Study. (Cr ar [may be repeated for cr]; prereq δ) Studies of approved topics, theoretical or experimental in nature.

EE 5478-5479. Industrial Assignment III-IV. (2 cr per qr; prereq 3477, regis in EE co-op program) Industrial work assignment in electrical engineering co-op program. Grade based on student’s formal written report covering the quarter’s work assignment.

EE 5490H-5491H-5492H Honors Project. (3 cr per qr; prereq δ) Design project for students in electrical engineering honors program.

For Graduate Students and Qualified Seniors


EE 5506. Analog Circuits for Signal Processing. (3 cr; prereq 5505 or grad standing or #) Review of filter types and Laplace and Fourier transforms; time and frequency-domain concepts; approximation methods (e.g., Butterworth, Chebyshev); frequency transformations. Ideal and non-ideal operational amplifiers, switched-capacitor filters; biquads and higher-order filters. Switched-capacitor gain stages, rectifiers and oscillators.


EE 5512. Adaptive Digital Filter Theory. (3 cr; prereq grad IT major, 5511, 5702 or #) Review of partial characterization of discrete-time random processes and correlation matrix eigenstructure. Auto regressive modeling: FIR Wiener filter theory; linear squares; LMS algorithm (transient and steady-state behavior); RLS algorithm; lattice structure.


EE 5514. Real-Time Digital Signal Processing Laboratory. (3 cr; prereq EE sr or IT grad or adult spec, 3352, 5002 or 5511 or #) Real-time computation of digital signal processing functions, including filtering, sample-rate change, and differential pulse code modulation. Implementation of a current digital signal processing chip. Study of the chip architecture, assembly language, and arithmetic. Consideration of real-time processing issues, including data quantization, limiting and scaling, processor limitations, and I/O handling.

EE 5515. Fast Fourier Transform and Convolution Algorithms. (3 cr; prereq 15002 or #) Theory and implementation of fast algorithms for discrete Fourier transform and convolution, including one- and multidimensional cases.

EE 5516. Digital Signal Processing Structures for VLSI. (3 cr; prereq 5002 or 5511 or #) Pipelining and parallel processing; FIR digital filters; fast convolution; parallel FIR digital filters; rank-order filters; architectures for FFT and DCT; pipelined IR filtering; stability, roundoff noise; parallel IIR digital filters; Schur polynomials, lattice IIR digital filters; adaptive filters.


EE 5571. VLSI Design I. (3 cr; prereq grad standing in EE, CSci or Phys or #) CMOS switch model, stick diagrams, restoring logic, and steering circuits. Process flows, layout design rules, and latch-up avoidance. Parasitic resistance and capacitance, delay models, design optimization, and worst-case design. Dynamic circuit techniques, including precharging. Domino CMOS, multiphase clocking, charge sharing, clock generation, and synchronization failure. Subsystem design, including multiplexers, registers, decoders, PLAs, finite state machines, adders, and function units.

EE 5572. VLSI Design II. (3 cr; prereq 5571 or #) Design methodologies, switch-level simulation, symbolic layout, and compaction. CMOS fault models, scan design, signature analysis, and built-in test. Computational unit design, including arithmetic-logic units, counters, fast multipliers, and barrel shifters. Memory architectures, RAM and ROM cells, sense amplifiers, content-addressable memory, and hardware stack. VLSI system case studies.

EE 5573. VLSI Design III. (3 cr; prereq 5572 or #) Register files, bus structures, pipelining, and fine-grained parallelism. Control structures based on random logic, PLAs, and ROMs. Multilevel control schemes and microsequencer design. RISC architectures, including overlapped register windows, delayed branching, pipeline interlocks, and hardware-software tradeoffs. Memory management units and cache design. VLSI system case studies.
EE 5574-5575f. Computer-Aided VLSI Design Laboratory. (3 cr per qtr; prereq IT sr or grad IT major or IT adult spec or # 5571 or #5571 for 5574, 5572 or 5572 for 5575)
Creative use of design aids in parameter extraction, schematic capture, chip layout, channel routing, maze routing, multilevel simulation, and artwork verification. Complete design of integrated circuits in MOS and bipolar technologies. Designs evaluated by computer simulation.

EE 5604. Introduction to Microwave Engineering. (3 cr; prereq EE sr or grad IT major, 3111 or equiv)

EE 5605. Microwave Devices and Circuit Applications. (3 cr; prereq 3111, 5604 or equiv or #)
Two-terminal devices including varactors, p-i-n diodes, step-recovery diodes, Gunn devices, and Impatt diodes for device physics and circuit applications as detectors, mixers, frequency converters, amplifiers, and oscillators. Three-terminal devices including FETs, heterostructure bipolar transistors, device physics, and circuit applications in amplifiers, oscillators, mixers, and frequency converters.

EE 5606. Antenna Theory and Design. (3 cr; prereq 3111 or #)
Fundamentals of antenna design for transmission and reception at radio and microwave frequencies. Antenna analysis techniques. Antenna applications including linear, loop, microstrip, aperture, and traveling wave antennas; broadband antennas and antenna arrays.

EE 5625. Fourier Optics. (4 cr; prereq 3011, 3111 or #)
Fourier analysis of optical systems and images with applications to spatial filtering, optical information processing, and holography. Fresnel and Fraunhofer diffraction. Current topics such as speckle interferometry, hybrid (optical-digital) information processing systems, and computer-generated holograms.

EE 5630. Contemporary Optics. (4 cr; prereq 3111 or Phys 5024 or #)
Fundamentals of lasers, including propagation of Gaussian beams, optical resonators, theory of laser oscillation, electro-optic and acousto-optic modulation, and nonlinear optics.

EE 5631. Photonic Devices. (3 cr; prereq EE sr or grad IT major, 5630 or 5661)
Photonic devices including optical properties of semiconductors, light-emitting diodes, lasers, and photodetectors.

EE 5634. Physical Optics: Applications and Techniques. (3 cr; prereq 5625 or #)

EE 5635. Optical System Design. (3 cr; prereq IT sr or grad IT major)

EE 5636. Optical Fiber Communication. (3 cr; prereq 3011, 3111 or #)

EE 5637. Physical Optics Laboratory. (3 cr; prereq 5625 or #)
Fundamental physical optical techniques, diffraction, optical pattern recognition, spatial and temporal coherence, speckle; interferometry, coherent and incoherent imaging, coherent image processing, fiber optics. Includes lab experiments at local industries.

EE 5650. Physical Methods in Solid-State Materials I. (3 cr; prereq EE sr or grad or adult spec, 3111)
Basic concepts in classical and statistical mechanics relevant to the properties of solid-state materials. Hamiltonian dynamics, statistical ensembles, phase space, partition function, classical and quantum statistics, relation between statistical mechanics and thermodynamics, Boltzmann transport theory.

EE 5651. Physical Methods in Solid-State Materials II. (3 cr; prereq EE sr or grad or adult spec, 5650 or #)
Applying quantum theory to solid-state materials. Schrödinger’s equation, one-dimensional problems, angular momentum, central forces, scattering, spin, atomic and chemical structure. Crystal structure in solids, lattice vibrations and phonons, energy bands.

EE 5652. Physical Methods in Solid State Materials III. (3 cr; prereq EE sr or grad or adult spec, 5651 or #)

EE 5661. Semiconductor Properties and Devices I. (3 cr; prereq EE sr or grad or adult spec, 3111, 5650 or #)

EE 5662. Semiconductor Properties and Devices II. (3 cr; prereq EE sr or grad or adult spec, 5661 or #)

EE 5665. Principles of Magnetic Recording and Laboratory. (4 cr; prereq EE sr or grad or adult spec)
Experiments with data storage devices designed to teach advanced data storage recording and retrieving schemes; physical properties.

EE 5666-5667. Magnetic Properties of Materials and Applications. (3 cr per qtr; prereq #)
5666: Magnetic measurement techniques, physical principles of magnetism, and properties of magnetic materials with applications. 5667: Physical principles of crystalline and induced magnetic anisotropy, magnetostriction, magnetic domains and the magnetization process, fine particles and thin films and magnetization dynamics.
EE 5669. Magnetic Recording. (3 cr; prereq EE sr or grad or adult spec) Review of fundamental magnetic concepts relevant to magnetic recording. Introduction to basic models of longitudinal and perpendicular magnetic recording and reproduction processes. Comparison of design, fabrication, and performance of conventional and thin film heads, tapes, disks, and recording systems.

EE 5670. Basic Microelectronics. (3 cr; 5670-5672; prereq EE sr or grad or adult spec; minimum grade of C in 5572 to receive cr) Experimental and theoretical studies of the basic physical processes used in microelectronic device fabrication. Transistor and integrated circuit layout, fabrication, and evaluation.

EE 5671. Advanced Microelectronics. (2 cr; prereq IT sr or grad, 5670 or 5672 or #) Integrating unit processes into fabrication technology; physics and chemistry of advanced techniques such as molecular beam epitaxy, electron beam lithography, and reactive ion etching.

EE 5672. Basic Microelectronics Laboratory. (1 cr; 5670-5672; prereq IT sr or grad or adult spec, 5670 or #5670) Design, fabricate, and test MSI level-integrated circuit. Unit operations.

EE 5673. Advanced Microelectronics. (3 cr; prereq IT sr or grad or adult spec, 5670, 5672 or #5670) See EE 5671.

EE 5680. Principles of Thin Film Technology. (4 cr; prereq IT sr or grad IT major) Introduction to principles of fabrication, characterization, and processing of thin films for engineering applications. High-vacuum systems, thin film deposition techniques, energetics and kinetics of thin film formation, and electrical, dielectric, magnetic, optical, and piezoelectric properties of thin films. Lab.

EE 5690. Fundamentals of Microelectromechanical Systems. (4 cr; prereq IT or health sciences major, #) Microelectromechanical systems composed of microsensors, microactuators, and electronics integrated onto common substrate. Design, fabrication, and operation principles. Labs on micromachining, photolithography, etching, thin film deposition, metallization, packaging, and device characterization.

EE 5700. Information Theory and Coding. (3 cr; prereq IT sr or grad or adult spec, Stat 3091 or #) Discrete information sources and channels, source encoding, the binary channel and Shannon’s theorem. Block codes for the binary channel.

EE 5701. Source Coding and Quantization. (3 cr; prereq IT sr or grad) Topics of practical interest. Lossless, subband, and transform coding; scalar and vector quantization; differential encoding; analysis/synthesis schemes.

EE 5702. Stochastic Processes and Optimum Filtering. (3 cr; prereq 3021 or Stat 3091, grad standing or #) Stochastic processes, linear system response to stochastic inputs. Gaussian process, Markov process. Linear filtering, maximum likelihood estimate, stochastic control.

EE 5703. Introduction to Detection and Estimation Theory. (3 cr; prereq IT grad, Stat 3091 or #) Hypothesis testing, parameter estimation, stochastic processes and their representation, stochastic processes through linear systems, waveform detection, estimation of signal parameter and waveform, Wiener and Kalman filters.

EE 5704. Digital Communication. (3 cr; prereq upper div EE or grad IT major, 5203, 3021 or Stat 3091 or #) Theory and techniques of modern digital communication: channel capacity; modulation and detection; data transmission over channels with large intersymbol interference; optimal and suboptimal sequence detection; equalization; error correction coding; trellis-coded modulation.

EE 5712. Kalman Filtering and Applications. (3 cr; prereq 5702, 3021 or Stat 3091, grad standing or #) Mathematical description of random signals; response of linear systems to random inputs. Discrete Kalman filter; applications. Continuous Kalman filter; smoothing; nonlinear extensions.

EE 5750. Topics in Linear Systems. (3 cr; prereq grad standing, Math 5242 or #) State variable and input/output models of linear systems. Controllability, observability, stability, minimality, and structure. State variable feedback and observers.


EE 5802. Electric Power System Analysis. (3 cr; prereq IT sr or grad or adult spec, 3010, 5300, 5310 or #) Formulating equations for describing electric power networks. Advanced computer methods for large-scale electric power systems. Application to the power-flow, faulted system calculations, and stability studies.
EE 5803-5804. Power Generation, Operation, and Control. (3 cr each; prereq IT sr or grad or adult spec, 3010, 5300, 5310 or #)
Economic dispatch of generation units, transmission system loss models, unit scheduling via dynamic programming and Lagrange relaxation algorithms, fuel and hydro scheduling via linear programming and transportation algorithms, energy production-costing algorithms, evaluation of energy transactions between suppliers, energy management systems, real-time control of generating units, system security evaluation, state estimation techniques, optimal power flow algorithms.

EE 5805. Electric Power System Engineering. (3 cr; prereq IT sr or grad adult spec, 3010, 5300, 5310 or #)
Control of large power systems. Power system overvoltages and transients caused by faults, switching surges, and lightning. AC and DC electric power transmission and distribution, overhead and underground. Environmental impact of electrical energy systems. Current research topics.

EE 5807. Power System Protection. (3 cr; prereq IT sr or grad or adult spec, 3010, 5300, 5310 or #)

EE 5814. Switched Mode Power Electronics. (3 cr; prereq IT sr or IT grad standing or IT adult spec, 3061, 3402 or #)
Overview of power capabilities and switching speeds of power semiconductor devices. Generic converter topologies and regulation techniques. Application and design of generic circuits such as switching power supplies, inverter devices for motors, battery chargers, uninterruptible power supplies, wind/photovoltaic inverters.

EE 5815. Switched Mode Power Electronics II. (3 cr; prereq IT sr or grad or IT adult spec, 5814 or #)
Limitations and methods of increasing power capabilities of switching devices. Device physics, switching characteristics, gate/base drives, stress reduction and loss considerations in using devices such as BJTs, MOSFETs, Gate-Turn-Off Thyristors. Future developments. Passive components and circuit layout in switched mode power electronics.

EE 5816. Switched Mode Power Electronics Laboratory. (2 cr; prereq IT sr or IT grad standing or IT adult spec, 5815 or #)
Switching characteristics of power semiconductor devices. Gate/base drives and snubbers. DC to DC converter circuits. Design and control of a switching power supply. Drives for dc-, induction-, "brushless" dc-, and stepper-motors. Battery chargers and uninterruptible power supplies. Other residential and industrial application.

EE 5820. Electromechanical System Dynamics. (3 cr; prereq #)

EE 5825. Finite-Element Methods in Electrical Engineering. (3 cr; prereq EE sr or IT grad, #)

EE 5851. Applied Switching Theory. (3 cr; prereq 3351, 3352 or #)

EE 5852-5853. Computer Organization and Design I-II. (3 cr per qtr; prereq 3351, 3352, 5851, 5852 for 5853)
Digital computer organization; register-level simulation; control unit design; microprogramming; memory organization. Input/output techniques; arithmetic unit design. Features of larger computers.

EE 5854. Advanced Computer Networks. (3 cr; prereq grad IT major or EE grad major or IT grad or IT adult spec, CSci 5211 or #)

EE 5858. Computer Architecture. (3 cr; prereq IT sr or IT grad standing or IT adult spec, 5853 or #)
Conventional and unconventional uniprocessor system design options. Impact of software on system architecture. Instruction set selection and architectural consequences. Memory systems including segmentation, paging, and cache memories. Control unit design. Object manipulation structures. Examples from current and historically important designs.

EE 5860. Microcomputer Architecture. (4 cr; prereq IT grad, 5355 or #)
Advanced microprocessor organization, 16- and 32-bit microprocessors, microprocessor bus structures, exception processing, interrupts, and virtual memory. Coprocessor organizations and multiprocessor systems. Design for testability. Integral lab.

EE 5863. Computer Systems Performance Analysis. (4 cr; prereq IT grad, 5858 or #)
Tools and techniques for measuring and analyzing computer hardware, software, and system performance. Benchmark programs, measurement tools, performance metrics. Presenting data, summarizing measured data, comparing system performance. Deterministic and probabilistic simulation techniques, random number generation and testing. Bottleneck analysis.

EE 5865. Coding Techniques and Applications. (3 cr; prereq grad IT major or #)
Linear error detecting/correcting codes, application to computers, polynomial description of codes, cyclic codes, encoder and decoder circuits, application to magnetic tapes, random test vector generation for self-test, signature analysis for data compression.
EE 5874. Simulation and Test in Digital Design.
(3 cr; prereq IT sr or grad or adult spec, 5851, CSci 3113 or equiv)
Theory and practice of simulation and test generation
algorithms in digital design.

EE 5952. Special Topics in Electrical Engineering.
(1-3 cr [may be repeated for cr]; prereq IT grad or adult
spec or #)
Topics vary.

EE 5953-5954. Special Topics in Electrical
Engineering. (1-3 cr [may be repeated for cr]; prereq
IT grad or adult spec or #)
Topics vary.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
EE 8060. Advanced Bipolar Transistor Theory
EE 8062. Heterojunction Microwave Devices
EE 8090. Electronics Seminar
EE 8100-8101. Advanced Engineering
Electromagnetics
EE 8110-8111. Plasma Physics
EE 8120-8121-8122. Fundamentals of Acoustics
EE 8140. Seminar: Plasma Physics
EE 8143. Seminar: Modern Optics
EE 8153-8154. Properties of Semiconductors
EE 8160. Quantum Electromagnetics I
EE 8164. Quantum Electronics II (Guided Wave
Optics)
EE 8170. Fluctuation Phenomena
EE 8180. Advanced Analog Integrated Circuits
EE 8181. Advanced Digital Integrated Circuits
EE 8185. Low-Power Analog Circuit Design
EE 8190. Seminar: Quantum Electronics
EE 8191. Seminar: Surface Physics
EE 8192. Seminar: Magnetics
EE 8203-8204. Signal Detection and Estimation Theory
With Applications
EE 8205. Image Processing and Applications
EE 8207. VLSI Architectures and Synthesis
EE 8211. Coding Theory I
EE 8212. Coding Theory II
EE 8220. Topics in Statistical Theory of
Communication
EE 8240. Seminar: Communication
EE 8250-8251-8252. Advanced Control Topics

EE 8253. Topics in Large-Scale Systems
EE 8257, 8258. Advanced Systems Theory I, II
EE 8260. Topics in Nonlinear Systems
EE 8290. Seminar: Control Theory
EE 8291. Seminar: System Theory
EE 8300-8301-8302. Advanced Power System
Topics
EE 8305. Sparse Matrix Methods in Power
System Analysis
EE 8340. Seminar: Electric Power
EE 8341. Seminar: Energy Conversion
EE 8342. Power Electronics: Utility Applications
EE 8352. Fault Diagnosis and Reliable Design
EE 8353. Sequential Circuit Theory
EE 8359. Computing With Neural Networks
EE 8360. Local Area Networks
EE 8362. Advanced Computer Architecture
EE 8363-8364. Parallel Processing I-II
EE 8370. Design of Intelligent Systems
EE 8390. Computer Systems Seminar
EE 8450. Special Investigations
EE 8451. Advanced Topics in Electrical Engineering
EE 8460. Plan B Project
EE 8461. Plan B Project
EE 8490, 8491, 8492. Graduate Seminar

Extractive Metallurgical Engineering (MetE)
For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
MetE 8000-8001. Applied Process Metallurgy I-II
MetE 8401-8402-8403. Seminar in Metallurgical
Engineering
MetE 8830. Electric and Magnetic Separation of
Minerals
MetE 8838-8839. Optimization and Control
Techniques in Mineral Processing I-II
MetE 8842. Surface Chemistry of Mineral
Suspensions
MetE 8921-8922-8923. Research in Extractive
Metallurgical Engineering
MetE 8930-8932-8934. Physical Chemistry of
High Temperature Metallurgical Reactions I-II-III
Geological Engineering (GeoE)

GeoE 5218. Design of Underground Excavations in Rock. (4 cr, §CE 5305; prereq IT or grad student, 5302 or #) Stresses and deformations around underground excavations in rock. Design of linings and support systems. Excavation by boring, drill, and blast. Tunneling under adverse conditions. Materials handling and tunnel ventilation.

GeoE 5260. Drilling, Blasting, and Commination. (4 cr; prereq IT or grad student, CE 3300 or #) Rock excavation and size reduction by drilling, blasting, and commination; basic mechanics of fracture; bit penetration into rock; properties of explosives; strain wave transmission, reflection and refraction in drilling and blasting; design of blasting rounds; tunnel boring machines. Types of crushing and grinding equipment and their selection.

GeoE 5262. Geological Engineering Analysis. (4 cr; prereq IT sr or grad IT major or #; 8 lab hrs per wk) Comprehensive analysis of a geological engineering or rock mechanics problem chosen by the student and staff. Involves the integration of concepts of rock and soil mechanics, geology and geophysics, mineral engineering and economics. Preparation of a professional report.


GeoE 5437. Computer Applications in Geologic Engineering. (4 cr, §CE 5021; prereq upper div CE or GeoE, CE 3020, Math 3251, Math 3252 or #) Three methods (finite differences, finite elements, boundary elements) for solution of problems in hydrology, structural engineering, geomechanics, and environmental engineering that reduce to partial differential equations. Each method illustrated in context of practical problems.

GeoE 5555. Engineering Geostatistics. (4 cr, §CE 5055; prereq sr or grad in CE or Geo or GeoE, Stat 3091 or #) Problem solving and decision making in geological engineering using the tools of applied statistics. Emphasis on spatially correlated data (i.e., variograms and Kriging). E.g., geologic site characterization, rock mass parameter estimation, ore body modeling, and optimal sample design for groundwater contamination assessment.

GeoE 5660-5661-5662. Special Geological Engineering Problems. (Cr and hrs ar; prereq IT sr or #) Literature survey, research work, or design study in geological engineering problems.

GeoE 5700. Systems Analysis for Geological Engineers. (4 cr; prereq upper div IT or grad student) Introduction to systems analysis and decision making: expert systems; operations research techniques, modeling, and simulation. Applications in geological engineering and related fields.

For Graduate Students Only

(For descriptions, see Graduate School Bulletin)

GeoE 8302. Soil/Rock Plasticity and Limit Analysis
GeoE 8336. Boundary Element Methods I
GeoE 8350. Advanced Rock Mechanics
GeoE 8360. Engineering Model Fitting
GeoE 8601-8602-8603. Seminar: Geological Engineering
GeoE 8612-8613-8614. Research Problems

Geology and Geophysics (Geo)

Geo 1001f,w,s. The Dynamic Earth: An Introduction to Geology. (4 cr; 3 lect, 1 2-hr lab per wk) Physical processes that shape the Earth (volcanoes, earthquakes, plate tectonics, glaciers, rivers). Current environmental issues and global change.

Geo 1002w,s. Historical Geology. (4 cr; 3 lect, one 2-hr lab per wk) Kirkby Evolution of Earth from its origin; the succession of physical and biological events of past 600 million years.

Geo 1003f,s,UC. Introduction to the Mesozoic: Evolution, Ecology, and Extinction of Dinosaurs. (4 cr) Kirkby Dinosaurs and the Mesozoic Era; plate tectonics, evolution, extinction, global change.


Geo 1011s. Volcanoes of the Earth. (4 cr; 4 lect hrs per wk) Stout Nonmathematical introduction to volcanoes, their origin and distribution on Earth and through time; theory of plate tectonics, origin of magmas and the Earth’s interior, products of volcanoes, types of eruptions and hazards, and impact on climate, vegetation, and society.

Geo 1012f. Planet Earth. (4 cr) Murthy Nonmathematical introduction to planet Earth. Relationships among various Earth systems—solid Earth, hydrosphere, atmosphere; various natural cycles that control the way the planet works and how human interactions disturb these cycles and their rates.

Geo 1019f,s,su,UC. Our Changing Planet. (4 cr, §Ast 1019, §EEB 1019) Murthy, staff Interrelationships among Earth’s subsystems—solid Earth, oceans, atmosphere, biosphere—and solar and galactic super-systems. Interactions of the natural cycles, their rates and feedbacks, and human impacts.
Geo 1044. Physical and Historical Geology of Minnesota. (4 cr; §1004) Southwick, Minnesota Geological Survey staff
See Geo 1004. Four local weekend field trips.

Geo 1081. Conspiracies, Fraud, and Deception in Earth History. (1 cr) Pfannkuch
Famous cases of geological deception from three centuries presented in the intellectual context of their time: Dr. Beringer’s lying stones from Germany, the great diamond hoax in San Francisco, and the Piltdown man fraud in Sussex.

Geo 1601w, UC. Oceanography. (4 cr; 3 lect, 1 lab hrs per wk) Barnwell, Paola
How various processes in the ocean interact; analogies between the oceans and Lake Superior and smaller lakes in Minnesota. Topics include marine biology, waves, tides, chemical oceanography, marine geology, and human interaction with the sea. Lab work includes study of live marine invertebrates and manipulation of oceanographic data.

Geo 1701. Faces of the Earth. (4 cr) Banerjee
History of pre-17th century ideas about geology in China, the Middle East, and Europe. Evolution of modern geology from travelers’ tales, cosmology, map making, minerals, volcanoes, and earthquakes. Relationship between humans and nature.

Geo 3001. Earth Materials. (2 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Study of the most common rocks and minerals and their geologic settings, focusing on the properties of these materials as a basis for identification as well as potential use.

Geo 3002. Climate Change and Human History. (4 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Causes of long- and short-term climate change; frequency and magnitude of past climate changes; geologic records of climate change; relationship of past climate changes to development of agrarian societies and shifts in balance of power among various kingdoms and city-states. Emphasis on last 10,000 years.

Geo 3003. Geohazards. (3 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Geologic hazards associated with earthquakes and volcanoes with emphasis on how society confronts these dangers. Geological and geophysical nature of earthquakes and volcanoes; fundamental causes of these phenomena; prediction and risk assessment; public policy issues.

Geo 3004. Human Geomorphology. (3 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Human interaction with the surface environment, including floods, erosion and sedimentation, landslides, and coastal-zone management. International case studies with emphasis on the influence of local land-use practices on how humans affect the environment and vice versa.

Geo 3005. Earth Resources. (4 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Geologic aspects of energy and material resources, including the international, citizenship, and public ethics issues associated with resource production, distribution, and use.

Geo 3006. Water and Society. (3 cr; prereq 1xxx geology course or #)
Study of global hydrologic cycle, water quality, and societal needs, emphasizing processes that influence the formation, circulation, and modification of the composition and use of water at or near the Earth’s surface. How humans influence the composition and use of water resources through agricultural, industrial, and other land-use practices.

Geo 3007. Planets of the Solar System. (3 cr; prereq 1001 or 1004 or 1012 or 1019 or #)
Recent accomplishments of space missions; diversity and common characteristics of planetary formation; surface processes and interior dynamics; meteoritic impacts and comets; other solar systems and the possibility of life elsewhere.

Geo 3111su. Introductory Field Geology. (4 cr; prereq 3202, #)
Geologic mapping on topographic maps and aerial photos; field identification of igneous, sedimentary, and metamorphic rocks; measurement of stratigraphic sections; study of structural and geomorphic features.

Geo 3201. Geodynamics I: The Solid Earth. (4 cr; prereq Phys 1251, 1252) Moskowitz, Stout
Introduction to the dynamics of the solid Earth, particularly the tectonic system.

Geo 3202. Geodynamics II: The Fluid Earth. (4 cr; prereq 3201) D Kohlstedt, Paola
Introduction to the dynamics of the fluid Earth, mainly surface processes and convection.

Geo 3211Hs. Honors Earth Science. (4 cr, $1001; prereq selection for IT honors curriculum or consent of IT Honors Office; 3 lect, 1 rec hrs per wk)
Applications of physics and chemistry to the Earth’s structure and dynamics.

Geo 3301. Geochemical Principles. (4 cr; prereq Chem 1051, 1052) Seyfried, Stout
Origin of the elements (nucleosynthesis, elemental abundances), geochemical classifications, isotopes (radioactive and stable), phase equilibria, and models of the Earth’s geochemical evolution. Basic geochemical processes that produced the Earth’s lithosphere, hydrosphere, and atmosphere.

Geo 3401w. Introductory Mineralogy. (4 cr; §5004; prereq 1001, Chem 1051, Math 1252 or #; 3 lect, 4 lab hrs per wk)
Crystallography, crystal chemistry, and crystal physics. Physical and chemical properties, crystal structures, and chemical equilibria of the major mineral groups. Lab includes crystallographic, polarizing microscope, X-ray powder diffraction exercises, and hand-specimen mineral identification.

Geo 3402s. Petrology. (4 cr; prereq 3401 or #)
Introduction to lithologic character and genesis of igneous and metamorphic rocks.

Geo 3990. Problems in Geology. (1-6 cr; prereq #, Δ)
Research or problem selected on basis of individual interests and background.

Geo 5004w. Mineralogy. (4 cr, §3401; prereq Chem 1051, Math 1252 or #; 3 lect, 4 lab hrs per wk)
See Geo 3401.

Geo 5010. Field Workshop. (2 cr; prereq Geo or Geophys or GeoE major or #)
Geologic or geophysical field study.

Geo 5020. Laboratory Workshop. (2 cr; prereq Geo or Geophys or GeoE major or #)
Geologic or geophysical lab study.

Geo 5030. Modeling Workshop. (2 cr; prereq Geo or Geophys or GeoE major or #)
Modeling of geologic or geophysical systems.
Geo 5051su,UC. Physical Geology for Teachers. (4 cr; §1001; prereq educ degree, 1 term college chemistry or physics) See Geo 1001. Students must complete a project designed to enhance their ability to teach Earth science to K-12 students.

Geo 5052su,UC. Historical Geology for Teachers. (4 cr; §1002; prereq educ degree, 1001 or 5051 or #) Introduction to origin of the Earth, physical evolution of its crust through geological time, and biological changes that occurred during its history. Lab, fieldwork, and seminar.

Geo 5054UC. Introduction to the Mesozoic for Teachers. (4 cr, §1003; prereq educ degree) Kirkby Dinosaurs and the Mesozoic Era; plate tectonics, evolution, extinction, global change. Students design modules to present course material to elementary or secondary school students.

Geo 5101. Geochronology and Stratigraphy. (4 cr; prereq 3301) Methods for measuring geologic time and dating rocks, both relatively and absolutely; correlation and other stratigraphic techniques.

Geo 5108w. Advanced Environmental Geology. (4 cr; prereq Geo core courses through 5201 or equiv or #) Pfannkuch Human impact on the geological environment and the effect of geology/geologic processes on human life from the point of view of ecosystems and biogeochemical cycles. Geologic limits to resources and carrying capacity of the Earth. Land use planning, environmental impact assessment, ecodeologic world models. Field project.

Geo 5111su. Advanced Field Geology. (4 cr; prereq 3111, #) Geologic mapping; study of igneous, metamorphic, and sedimentary rocks; structures and surficial features; problem solving. Paper required.


Geo 5113su. Geophysical Field Methods. (4 cr; prereq 3111 or equiv, #) Gravity, magnetic seismic refraction, seismic reflection, electrical resistivity, and electromagnetic methods. Near-surface and upper-crustal problems studied using appropriate field design and methods. Interpretational methods, including preliminary “rule of thumb” interpretations at the site and quantitative methods in the lab.

Geo 5151f. Introduction to Paleontology. (5 cr; prereq 1002 or #) Morphology, classification, and ecology of selected major fossil groups.

Geo 5201s. Structural Geology. (4 cr; prereq 3402, 5101 or #) Teyssier Deformation of the Earth’s crust. Processes associated with deformation, faulting, folding, and fabric development; labs and recitations include solving problems and conducting physical and numerical experiments; field trips offered.

Geo 5202. Tectonic Styles. (3 cr; prereq 5201 or #, 3 lect hrs per wk; offered alt yrs) Hudleston Origin and nature of major types of disturbances affecting the continental crust, including analysis of the form and development of individual structural components.

Geo 5203w. Geotectonics. (3 cr; prereq 5201 or #; offered alt yrs) Kleinspehn, Teyssier Problems associated with global tectonics; structure and evolution of the Earth’s crust and lithosphere; study of active compression, extensional, and wrench tectonic regimes, with many examples from various parts of the world; interpretation of older tectonic systems.

Geo 5251s. Geomorphology. (4 cr [5 cr with term project]; prereq 1001, Math 1031 or #, 3 lect, 2 lab hrs per wk, lab often used for field trips) Hooke Origin, development, and continuing evolution of landforms in various environments. Environmental implications emphasized. Weathering, slope and shore processes, fluvial erosion and deposition, wind action, tectonics, and impact phenomena.

Geo 5252w. Regional Geomorphology. (3 cr; prereq 5201 or #; offered alt yrs) Hooke Geology of a particular region of the country and its geomorphology. One-week field trip to the area late in the quarter.

Geo 5255w. Glaciology. (4 cr [5 cr with term project]; prereq Math 3261 or #) Hook Determination of the flow rate and basal conditions of glaciers using a computer model. The glacial regime and its influence on the land surface.

Geo 5256f. Glacial Geology. (4 cr [5 cr with field trips]; prereq 1002 or #) Formation and characteristics of modern glaciers; erosional and depositional features of Pleistocene glaciers; history of Quaternary environmental changes in glaciated and nonglaciated areas. Field trips.

Geo 5311. Geochemical Processes. (4 cr; prereq 3301, Chem 5501 or #) Ito, Seyfried Processes pertaining to distribution and control (structural, thermodynamic, kinetic) of chemical species in Earth and hydrosphere.

Geo 5313s. Aqueous Geochemistry. (4 cr; prereq 5311, Chem 5501 or #) Seyfried General principles of solution chemistry with application to geology, including solution-mineral equilibria, redox and kinetic processes, and chemical evolution of natural waters.

Geo 5321. Isotope Geology. (4 cr; prereq 3301 or #; offered alt yrs) Alexander, Ito Introduction to theory and uses of radioactive, radiogenic, and stable isotopes in geology. Radioactive dating, geothermometry, and tracer techniques in geologic processes.

Geo 5452s. Igneous and Metamorphic Petrology. (5 cr; prereq 3402, Chem 5501, Math 3261 or #) Stout Theoretical course that develops basic thermodynamic tools and chemographic analysis for interpreting chemical processes in igneous and metamorphic rocks. Lab, field trip, problem sets, term paper.

Geo 5454. Electron Microprobe Theory and Practice. (2-4 cr; prereq 3401, 1 yr chem and phys or #) McSwiggen Characterizing solid materials with electron beam instrumentation, including the reduction of X-ray data to chemical compositions.
Geo 5505f. Solid-Earth Geophysics I. (4 cr; prereq 3201, Phys 1253)
Elasticity, seismology; physical structure of the Earth’s crust and deep interior.

Geo 5506w. Solid-Earth Geophysics II. (4 cr; prereq 3201, Phys 1253)
Earth’s gravity fields; mantle viscosity, paleomagnetism, seismic tomography, basic mantle convection and thermal history.

Geo 5507s. Solid-Earth Geophysics III. (4 cr; prereq 3201, Phys 1253)
Mechanical properties and transport processes in Earth materials with emphasis on their importance to a range of geophysical phenomena.

Geo 5508. Mineral and Rock Rheology. (4 cr; prereq 3201, Phys 1253)
Elastic, anelastic, and viscous deformation of minerals and rocks. Materials science fundamentals and geological/geophysical applications.

Geo 5515w. Principles of Geophysical Exploration. (4 cr; prereq Phys 1253)
Seismic exploration (reflection and refraction), potential techniques (gravity and magnetics), and electrical techniques of geophysical exploration.

Geo 5522. Times-Series Analysis of Geological and Geophysical Phenomena. (4 cr; prereq Math 3221 or #; offered alt yrs)
Linear and nonlinear geological and geophysical phenomena; ice age cycles, earthquakes, climatic fluctuations, volcanic eruptions, atmospheric phenomena, thermal convection and other time-dependent natural phenomena; nonlinear dynamics and complexity theory.

Geo 5535w. Geological Thermomechanical Modeling. (4 cr; prereq Math 3261 or #; offered alt yrs)
Yuen
Concept of heat and mass transfer processes in the Earth’s crust and mantle. Quantitative study of thermomechanical phenomena. Emphasis on both analytical and modern numerical techniques.

Geo 5541f. Geomagnetism. (4 cr; prereq 3201, Math 1251, Phys 1251 or #; offered alt yrs)
Banerjee
Present geomagnetic field at the Earth’s surface and at the core-mantle boundary, secular variation, paleointensity variation, geomagnetic field reversal, models for field transition.

Geo 5543. Paleomagnetism. (4 cr; prereq 3201, Math 1251, Phys 1251 or #; Moskowitz)
Physical and chemical basis of paleomagnetism. Origin of natural remanent magnetization and its stability, mineralogy of magnetic minerals, paleomagnetic measurement techniques, statistics of paleomagnetic data, magnetic polarity stratigraphy, apparent polar wander, environmental magnetism.

Geo 5561s. Magnetism: Physics, Geophysics, and Engineering. (3 cr, §EE 5561, §Physics 5561; prereq Phys 1251; offered alt yrs; Moskowitz, staff)
Elementary statistical mechanics, rock magnetism, micromagnetic modeling. Applications of magnetism in geophysics, biomagnetism, magnetic sensors, and recording.

Geo 5601f. Limnology. (4 cr; §EEB 5601; prereq Chem 1052 or equiv)
Events occurring in lakes, reservoirs, and ponds, from their origins through the study of their physics, chemistry, and biology. Emphasis on interrelationships of these parameters and on effects of civilization on lakes.

Geo 5603. Geological Limnology. (4 cr; prereq 5601 or EEB 5601)
Tectonic and climatic setting of lakes; physical, chemical, and biological processes of sedimentation in lakes.

Geo 5613f. Karst Hydrogeology and Tracer Applications. (4 cr; prereq 5641, #; offered alt yrs; Alexander)
Karst hydrogeology and application of tracers to determine the source, age, and mixing parameters of water in various natural reservoirs. Physical and chemical principles and processes operating in karst hydrogeology and the use of natural and synthetic chemical and isotopic labels or tracers to follow the movement and mixing of water through the hydrologic cycle.

Geo 5621. Limnology Laboratory. (2 cr, §EEB 5621; prereq 5601 or EEB 5601 or #)
Lab to accompany Geo 5601 (EEB 5601). Techniques for obtaining information about conditions in lakes and streams. Procedures for measuring abundance and population dynamics of aquatic organisms, with emphasis on plankton. Field instruments, sampling devices, chemical analyses, microscopy, and analysis of data. One Saturday field trip.

Geo 5631s. Earth-System: Geosphere/Biosphere Interactions. (4 cr, §EEB 5604; prereq 3202, 3301 or #; Davis, Kelts)
Interdisciplinary study of global change forcing mechanisms, feedbacks, and dynamics on various time scales using paleorecord to illustrate processes.

Geo 5641f. General and Physical Hydrogeology. (4 cr; prereq 1001, Chem 1052, Math 1252, Phys 1105, Geo major core curriculum through 3402 or #; Pfannkuch)
Theory of groundwater geology, hydrologic cycle, watershed hydrology, Darcy’s law, governing equations of groundwater motion, flow net analysis, analog models, groundwater resource evaluation and development.

Geo 5642s. Quantitative Hydrogeology. (4 cr; prereq 1001, Chem 1052, Math 1252, Phys 1105, Geo major core curriculum through 3402 or #; Person)
Applied analysis of steady and transient equations of groundwater motion and chemical transport using analytical and numerical methods. Numerical flow net analysis, well hydraulics, salt-water intrusion problems, unsaturated flow.

Geo 5643w. Chemical Hydrogeology. (4 cr; prereq 1001, Chem 1052, Math 1252, Phys 1105, Geo major core curriculum through 3402 or #; Alexander)
Chemistry of natural waters, acid-base and redox reactions, carbonate equilibria, contaminant hydrogeology, isotope hydrology, chemical modeling.

Geo 5651. Sedimentology. (4 cr; prereq 3402, upper div IT major in Geo or Geophysics or GeoE or CLA jr or sr Geo major or #; Paola)
Interpretation of origin of sedimentary rocks through application of basic physical and chemical principles, understanding of modern depositional environments, and petrographic microscopy.
COURSE DESCRIPTIONS

Geo 5653. Stratigraphy and Basin Analysis. (4 cr [6 cr with lab]; prereq 5651 or #; offered alt yrs) Kleinsepp
Modern techniques and principles of stratigraphic analysis of sedimentary basins in various tectonic settings. Topics include seismic stratigraphy, correlation techniques, paleocurrent analysis, computer basin modeling, and geochronology of sedimentary basins.

Geo 5654. Marine and Lacustrine Sedimentary Environments. (4 cr; prereq 5651 or #; offered alt yrs) Kleinsepp
Facies analysis of modern and ancient depositional systems including deltas, fan deltas, barrier islands, beaches, storms, and turbidity currents in lakes and marine settings. Interpretations of marine tidal systems, carbonate platforms, reefs, continental shelves and abyssal-plain processes.

Geo 5655. Continental Sedimentary Environments. (4 cr; prereq 5651 or #; offered alt yrs) Kleinsepp
Principles of facies analysis of modern and ancient non-marine depositional systems.

Geo 5656. Depositional Mechanics. (3-4 cr; prereq 5651, Math 3261 or #; offered alt yrs) Paola
Elementary mechanics of sediment transport applied to quantitative interpretation of sedimentary rocks.

Geo 5701. Scientific Visualization. (4 cr; prereq CSci 3101, CSci 3102 or CSci 3113 or #)
Practical application to evaluating data from diverse fields, including geology, geophysics, engineering, and medicine.

Geo 5980. Seminar: Current Topics in Geology and Geophysics. (1-6 cr; prereq #)

Geo 5990. Senior Thesis. (2 cr per qtr [max 6 cr]; prereq sr Geo or Geophys major, #)
Non-structured research course enabling senior-level majors to do independent research with faculty supervision. Selection of suitable problems according to individual interests and by consultation with faculty committee. Thesis and oral defense.

For Graduate Students or for Seniors With Special Permission
(For descriptions, see Graduate School Bulletin)

General Geology
 Geo 8097. Seminar: Current Topics in Geology and Geophysics
 Geo 8098. Seminar: Current Topics in Geology and Geophysics
 Geo 8099. Research in Geology and Geophysics
 Geo 8202. Advanced Structural Geology
 Geo 8203. Geotectonics
 Geo 8262. Quaternary Paleoclimatology and Climate
 Geo 8351. Geochemical Modeling of Aqueous Systems
 Geo 8453. Phase Equilibria in Mineral Systems
 Geo 8455. Metamorphic Petrology
 Geo 8602. Advanced Limnology
 Geo 8612. Analytical Geochemistry
 Geo 8617. Transport Phenomena in Natural Porous Media
 Geo 8618. Finite Element Methods in Subsurface Flow and Transport Problems
 Geo 8620. Geofluids Seminar: Fluid Flow and Geologic Processes Within the Earth’s Crust
 Geophysics
 Geo 8522. Time-Series Analysis of Geological and Geophysical Phenomena
 Geo 8543. Principles of Rock Magnetism
 Geo 8571. Advanced Geodynamics

History of Science and Technology (HSci)

Courses may be taken to support existing majors or for a minor in this field, as well as to broaden knowledge of the nature and development of science and technology.

The following courses as indicated, may be used to fulfill liberal education requirements. Consult the quarterly Class Schedule for current offerings.

HSci 1711, 1712, 1713. Technology and Western Civilization. (4 cr per qtr, §3711, §3712, §3713)
Layton, Seidel
History and sociocultural relations of Western technology. 1711: Relations of technology to culture from the Bronze Age to the Middle Ages. 1712: Technology and science in the Renaissance; technology and the scientific revolution; emergence of industrialism. 1713: Diffusion of the industrial revolution; technological development and its impact on industry, government, and society. (Fulfills History and Social Sciences and International Perspectives)

HSci 1811, 1812, 1813. Introduction to History of Science. (4 cr per qtr, §3811, §3812, §3813)
Norberg, Shapiro
1811. Ancient: Babylonian and Egyptian science; Greek natural philosophy, mathematics, astronomy, and biology; the Aristotelian world; decline and transmission of Greek science. 1812. The Scientific Revolution: Medieval background; the “experimental philosophy”; dissecting and describing nature; anatomy, circulation, and respiration; Copernican revolution; physical world of Kepler, Galileo, Descartes, and Newton; science and the popular imagination. 1813: Modern Science: 19th and 20th centuries; Newtonian triumph, romantic reaction, and modern revolution; the aether, electrical and optical, to Einstein; history of the Earth; evolution before and after Darwin; nuclear physics and nuclear weapons. (Fulfills History and Social Sciences and International Perspectives)

HSci 3201, 3202. History of Biology. (4 cr per qtr, §5201, §5202) Beatty
Scientific, philosophical, and social factors in the development of biology; changing styles of biological reasoning, and changing relationships between the biological and physical sciences. 3201: Biology from antiquity through the early modern period. 3202: Biology in the 19th and 20th centuries. (Fulfills History and Social Sciences and International Perspectives)
History of computing developments in the last century with
equal attention to factors affecting the evolution of hardware
and software, the growth of the industry and its relation to
other business areas, and the changing relationships
resulting from new data gathering and analysis techniques.

HSci 3331. Technology and American Culture. (4 cr, §5331) Layton, Norberg
Historical survey of the development of American
technology in its cultural and intellectual context from the
colonial period to the present. Includes transfer of
technology to America; establishment of an infrastructure
promoting economic growth; relationships among
government, corporate, and academic influences; and the
social response to technological developments.

HSci 3332. Science and American Culture. (4 cr, §5332) S Kohlstedt, Norberg
Historical survey of the development of American science,
including the transfer of science to America; development of
indigenous traditions for the pursuit of science;
establishment of an infrastructure for education and
research; response of the public to scientific development;
and the relationships among government, corporate, and
academic scientists. (Fulfills History and Social Sciences
and Cultural Diversity)

HSci 3333H. Twentieth-Century American
Science. (4 cr) S Kohlstedt
Historical approach to understanding science and
technology within intellectual, political, and social contexts;
decision making by practitioners on issues of importance to
the professional and community; topics relating to popular
science, science and warfare, and basic institutions for
science and technology.

HSci 3401. Engineering Ethics in Historical
Perspective. (4 cr, §5401) Layton, Seidel
Historical survey of engineering ethics in the United States.
Successful and unsuccessful strategies for dealing with
ethical issues compared using case studies. Emphasis on
recent cases such as the Challenger and DC-10 disasters,
seen in historical perspective.

HSci 3402. Science, Ethics, and Values. (4 cr)
Seidel
Historical approach to ethical questions: Is there a scientific
ethic? What ethical standards govern scientific and
technological work in the late 20th century?

HSci 3502. History of High-Technology Weapons. (4 cr)
Seidel
Relationship of high-technology weapons to warfare in the
modern period (1500-1900), including the role of such
weaponry in imperialism, the arms race, and civil and
military contexts.

HSci 3711, 3712, 3713. Technology and Western
Civilization. (4 cr per qtr, §1711, §1712, §1713)
See HSci 1711, 1712, 1713. (Fulfills History and Social
Sciences and International Perspectives)

HSci 3811, 3812, 3813. Introduction to History
of Science. (4 cr per qtr, §1811, §1812, §1813)
See HSci 1811, 1812, 1813. (Fulfills History and Social
Sciences and International Perspectives)

HSci 3825. The Nuclear Age. (4 cr; prereq 5825) Stuewer
Origin, development, and social impact of nuclear physics
from the beginning of the 20th century through the post-
World War II era. Experimental discoveries; theoretical
models of the nucleus; refugees from Nazism; construction
and use of the atomic bomb; Oppenheimer and McCarthyism.

HSci 5011. Theories of Color: Newton to
Helmholtz. (4 cr) Shapiro
Physical and physiological investigations of color from the
17th to the mid-19th centuries, focusing on fundamental
contributions of Newton, Young, Maxwell, and Helmholtz.

HSci 5111. Physical Sciences in Antiquity. (4 cr)
Shapiro
Mathematics and astronomy in Babylonia; Greek
mathematics, Euclid and Archimedes; Aristotle’s physics
and cosmology; the emergence of mathematics and
experimental and natural science in Greece; Ptolemaic
astronomy.

HSci 5113. Natural Philosophy in the Scientific
Revolution. (4 cr) Shapiro
Emergence of modern science in 17th century. Development
of scientific method (nature of scientific explanation,
experiment, quantitative approach) and new conceptual
basis for physical world (space, matter, force). Bacon,
Galileo, Descartes, Boyle, and Newton, among others.

HSci 5201, 5202. History of Biology. (4 cr per qtr,
§3201, §3202)
See HSci 3201, 3202.

HSci 5242. The Darwinian Revolution. (4 cr;
prereq Biol 1009 or 1101 or #) Beatty
Pre-Darwinian conceptions of nature; development and
reception of Darwin’s theory of evolution by natural
selection; also the broader context of the Darwinian
Revolution, including religious thought, political theory, and
views about proper scientific methodology.

HSci 5244. History of Ecology and
Environmentalism. (4 cr)
Historical development and interaction of ecology as
profession and political stance; conservation, Dust Bowl era,
population control, DDT controversy, international
environmental issues.

See HSci 3321.

HSci 5331. Technology and American Culture. (4 cr, §3331) Norberg
See HSci 3331.

HSci 5332. Science and American Culture. (4 cr,
§3332) S Kohlstedt
See HSci 3332.

HSci 5401. Engineering Ethics in Historical
Perspective. (4 cr, §3401)
See HSci 3401.

HSci 5511. History of Scientific Methodology. (4 cr) Beatty
Changing views of the aims and methods of science as seen
through the eyes of philosopher-scientists of the past; how
notions of “explanation,” “hypothesis,” “evidence” have
changed through time.
HSci 5681. Engineering in History. (4 cr) Layton
Civil and mechanical engineering since the Industrial
Revolution; complementary roles played by structures and
machines in the history of technology. Interaction of
structure with aesthetics and machines with science.

HSci 5825. The Nuclear Age. (4 cr, § 3825) Stuewer
See HSci 3825.

HSci 5924. History of 19th-Century Physics. (4 cr,
§Phy 5924; prereq general phys or #) Stuewer
Experimental and theoretical discoveries in 19th-century
physics (wave theory of light, atomic theory, heat,
thermodynamics and statistical mechanics,
electromagnetism and field theory) set within the context of
concurrent educational, institutional, and political
developments in Europe and the United States.

HSci 5925. History of 20th-Century Physics. (4 cr,
§Phy 5925; prereq general phys or #) Stuewer
Experimental and theoretical discoveries in 20th-century
physics (birth of modern physics, special theory of
relativity, old and new quantum theories) set within the
context of concurrent educational, institutional, and political
developments in Europe and the United States.

HSci 5935. History of Nuclear Physics. (4 cr;
prereq general phys or #) Stuewer
Experimental and theoretical developments in nuclear
physics to World War II in their institutional, social, and
political contexts. Life and work of Becquerel, Curie,
Rutherford, Chadwick, Gamow, Lawrence, Fermi, Bohr,
Hahn, Meitner, others.

HSci 5970. Directed Studies. (1-15 cr per qtr;
prereq #)
Guided individual reading or study.

HSci 5990. Directed Research. (1-15 cr per qtr;
prereq #)
For Graduate Students Only
(For description, see Graduate School Bulletin)

HSci 8111. Historiography of History of Science
and Technology
HSci 8121. Foundations for Research in Ancient
Science
HSci 8122. Foundations for Research in the
Scientific Revolution
HSci 8900. Seminar: History of Early Physical
Sciences
HSci 8910. Seminar: History of Modern Physical
Sciences
HSci 8920. Seminar: History of Biological Sciences
HSci 8930. Seminar: History of Technology
HSci 8940. Seminar: History of Science and
Technology in America
HSci 8941. Women in Science: Historical
Perspectives
HSci 8950. Science and Technology in Cultural
Settings

Industrial Engineering/Operations Research (IEOR)

Many of the courses listed below have honors
sections available. Contact the Student
Advising and Information Office, 121
Mechanical Engineering, for more information.

IEOR 3000. Introduction to Industrial
Engineering Analysis. (4 cr; prereq IT student, Math
1252; 3 lect, 1 rec hrs per wk)
Elements of manufacturing and production systems, types of
industrial problems solved by the industrial engineer,
problem-solving methodology for IE problems, linear
programming, artificial intelligence techniques, methods
engineering for process improvement, critical path method
and PERT, fundamentals of engineering economy, cost
estimation, value engineering, concurrent engineering,
design for manufacture. Applications may include
production scheduling, facility layout, quality engineering,
manufacturing automation, product design.

IEOR 5010. Introduction to Work Analysis. (4 cr;
prereq IT or grad student, 3000; 3 lect, 1 rec hrs per wk)
Fundamentals of methods engineering, work measurement,
and plant layout; charting techniques, process charts,
predetermined time systems, work sampling, time study,
master standard data, cross charting, and line balancing.

IEOR 5020. Engineering Cost Accounting,
Analysis and Control. (4-5 cr; prereq IT or grad
student; 3000, ME 3900 recommended; 3 lect, 1 rec hrs
per wk)
Basic accounting concepts, financial statements, analysis
and control of current assets such as cash, receivables, and
inventory; income tax planning, cost analysis, standard costs
for product costing, time value of money, quantification of
risk and uncertainty, utility theory, cost of capital and capital
structure, capital budgeting under capital rationing,
management decisions, and investment decisions.

IEOR 5030. Quality Engineering. (4 cr; prereq IT or grad
student, Math 1261, ME 3900 recommended; 3 lect, 1 rec hrs
per wk)
Definitions of quality, quality strategy, economics of
quality, quality improvement teams, improvement
methodologies, the 7 QC tools, control charts, rational
sampling, process capability analysis, quality in product
design, quality function deployment, total quality
management, Deming management methods.

IEOR 5040. Introduction to Operations Research.
(4 cr; prereq IT or grad student, Math 1261; IEOR 3000
recommended; 3 lect, 1 rec hrs per wk)
Linear programming, algebra and geometry of linear
models, simplex method, sensitivity testing, and duality;
network models, network algorithms, and dynamic models.

IEOR 5050. Engineering Economic Analysis. (4 cr;
prereq IT or grad student, 3000 or #; 3 lect, 1 rec hrs
per wk)
Fundamental principles and techniques of economic analysis
of engineering projects including economic measures of
effectiveness, time value of money, cost estimation,
depreciation, taxes, break-even, replacement and investment
analysis.
INDUSTRIAL ENGINEERING/OPERATIONS RESEARCH

IEOR 5070. Introduction to Human Factors Engineering. (4 cr; prereq IT student, grad or public health major, #; 3 lect, 1 rec-lab hrs per wk)
Analysis and design of operations, machines, equipment, work stations, and work environments relative to the capabilities, limitations, and needs of the human operator. Topics include human-machine systems, displays, controls, human-machine interface layout, workstation design, anthropometry, work physiology and biomechanics, illumination, noise, toxicology, and climate.

IEOR 5071. Human Factors in System Design. (4 cr; prereq 5010 or 5070; 1 lect/rec, 3 hrs scheduled field work per wk)
Application of the theory and principles from IEOR 5070 and 5010 to the analysis and design of real industrial work settings in local industry.

IEOR 5180, 5181. Applied Industrial Engineering. (3-5 cr [1- or 2-cr term paper option]; prereq background in all basic industrial engineering areas [3000, 5010, 5020, 5030, 5040])
Industrial engineering surveys and programs, case problems, studies in local plants.

IEOR 5221. Facilities Planning. (4 cr; prereq IT or grad student, 5010, 5020, 5040; 3 lect, 1 rec hrs per wk)
Facilities planning process, relationship to product design, process planning and market requirements, facility location, financial analysis of facility plans, systematic layout planning, computerized layout planning, mathematical modeling, material handling, warehousing.

IEOR 5254. Design Morphology With Applications. (4 cr; prereq upper div ME, completion of sequences ME 3201-3203-3205 or ME 3303 or ME 5342 or #; 1 lect, 7 lab hrs per wk)
Detailed study of design problem formulation and structure of the open-ended solution process based on design morphology. Case studies and student projects as instructional vehicles.

IEOR 5255. Engineering Design Project. (4 cr, [may be repeated for cr]; prereq upper div ME, 5254; 1 lect, 7 lab hrs per wk)
Participation in solving systems design problems that have developed criteria, order-of-magnitude evaluation of alternatives, generation of preliminary designs.

IEOR 5311. Management for Engineers. (4-5 cr [1- or 2-cr term paper option]; prereq IT or grad student, 3000; 3 lect hrs per wk)
Historical development of management concepts; organizational systems and authority relationships; planning, communication, and management responsibility.

IEOR 5321. Industrial Safety. (4 cr; prereq IT or grad student, 3000; 4 lect hrs per wk)
Definition and philosophy of safety, safety training, safety requirements for production processes, equipment and plants, industry standards, safety devices, and product safety.

IEOR 5351. Analysis of Production Processes. (4 cr; prereq IT or grad student, 5020; background in all basic industrial engineering areas [3000, 5010, 5030, 5040] recommended; 4 lect hrs per wk)
Problems in production engineering and production management. Analysis of production problems from selected industries. Development of ability to recognize and diagnose industrial problems.

IEOR 5361. Inventory and Production Control. (4 cr; prereq IT or grad student, 3000, 5040, ME 3900; 3 lect, 1 rec hrs per wk)
Forecasting techniques and analysis of inventory systems, aggregate planning, capacity decision, scheduling techniques, line balancing, use of linear programming models in the design, operation, and control of production and distribution systems.

IEOR 5441. Operations Research II. (4 cr; prereq IT or grad student, 5040; 3 lect, 1 rec hrs per wk)
Graph theory, network flow problems, heuristic search, integer and dynamic programming. Industrial applications may include product design, manufacturing planning, facility layout, scheduling, vehicle routing.

IEOR 5442. Operations Research III. (4 cr; prereq IT or grad student, 5441; 3 lect, 1 rec hrs per wk)
Optimization in probability models, Markov chains, queuing theory, and simulation.

IEOR 5445. Topics in Management Science. (3-5 cr [1- or 2-cr term paper option]; prereq IT or grad student; background in all areas of industrial engineering [5010, 5020, 5030, 5040] recommended; 3 lect hrs per wk)
Specialized topics in management science. Analytical tools for decision making and management of the production function. Emphasis on topics appearing in the current literature. Topics vary quarterly.

IEOR 5446. Discrete Event Simulation: Introduction and Applications. (4 cr; prereq Math 1231, ME 3900, IT grad; 3 lect, 1 rec hrs per wk)
Develop, run, and interpret discrete event simulation models with an emphasis on manufacturing systems. Gain experience with an entity-attribute PC-based simulation language with graphics capability. Statistics issues raised via experimentation. Industry-based course project.

IEOR 5480. Human-Machine System. (4 cr; prereq 5070 or #; IT or grad student; 3 lect, 1 rec hrs per wk)
Applications of mathematical methods for development of quantitative descriptions and models of human performance with relevance to engineering design. Emphasis on information processing, control, and decision making.

IEOR 5550. Design and Analysis of Experiments I. (4 cr; prereq IT or grad student, ME 3900; 3 lect, 1 rec hrs per wk)
Theory of variation, scientific method, independent and paired t-tests, analysis of variance, diagnostic checks, model building, gull and fractional factorial designs, Taguchi designs, response surface methodology.

IEOR 5551. Design and Analysis of Experiments II. (4 cr; prereq IT or grad student, 5550, ME 3900; 3 lect, 1 rec hrs per wk)
Experiments of two or more factors. Designs involving crossed, nested, and mixed classifications; orthogonal polynomials; block confounding; fractional factorial designs; and computer programs for analysis.

IEOR 5703. Engineering Project Management. (4 cr, §CE 5703; prereq IT sr or grad or equiv)
Broad practical understanding of project management, including planning, scheduling, budgeting, staffing, and task and cost control; how to communicate with, motivate, and manage team members.
COURSE DESCRIPTIONS

IEOR 5990. Topics in Industrial Engineering. (4 cr; prereq IT student or grad; 5010, 5020, 5030, 5040 recommended [may be repeated for cr]; 4 lect hrs per wk) Specialized topics within various areas of industrial engineering. Emphasis on topics of current interest. Topics vary quarterly.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

IEOR 8110-8111-8112. Advanced Industrial Engineering
IEOR 8310-8311. Production Engineering Problems
IEOR 8410-8411-8412. Industrial Engineering Research
IEOR 8430. Nonlinear Programming
IEOR 8773-8774-8775. Graduate Seminar

Special Interest Courses for IT Students (IofT)
See page 47.

Materials Science and Engineering (MatS)

MatS 3400. Introduction to Mechanical Properties. (4 cr; prereq 2nd-yr IT student; 3 lect, 1 rec or 2 lab hrs per wk) Introduction to the structure-property relationships of metals, alloys, and polymers. Crystal structure, diffusion, and the theoretical basis of elasticity and plasticity will be related to practical topics. Includes materials processing lab/recitation with emphasis on engineering alloys and heat treatment.

MatS 3600H. Introduction to Materials Science, Honors. (4 cr; prereq selection for IT honors program or consent of IT Honors Office; 3 lect, 1 rec hrs per wk) Introduction to the properties of solids. Chemical bonding, crystal structures, defects, structure-property relationships, phase diagrams; properties of metals, ceramics, semiconductors, including transport properties and microelectronic devices.

MatS 5011. Introduction to the Science of Materials. (4 cr; prereq upper div ChEn or MatS major or #; 3 hrs lect, 2 rec hrs per wk) General introduction to materials. Metals, polymers, ceramics, glasses, composites, electrical and magnetic materials.

MatS 5012. Introduction to Dislocations and Physical Metallurgy. (4 cr; prereq upper div IT, 3400, 5011, AEM 3016 or #; 3 lect, 2 rec hrs per wk) Basis of work hardening, solid solution strengthening, precipitation hardening, and heat treatment of alloys.

MatS 5013. Introduction to Electrical and Magnetic Properties of Materials. (4 cr; prereq upper div IT, 5011 or #; 3 lect, 2 rec hrs per wk) Introduction to quantum mechanics and semi-quantitative theories on electrical and magnetic properties of solids.

MatS 5101. Thermodynamics of Solids. (4 cr; prereq Chem 5534 or #; 3 lect, 1 rec hrs per wk) Fundamental concepts, 1st and 2nd laws, free energy, equilibrium constant, fugacity and activity relationships, solution models, order-disorder.

MatS 5102. Diffusion and Solid-State Kinetics. (4 cr; prereq upper div IT, 5101, ChEn 5001 or #; 1 rec hrs per wk) Kinetics: concepts of reaction rate control by various processes, using gas-solid reactions as an example. Diffusion: interstitial and substitutional diffusion, steady-state and transient systems.

MatS 5112. Ceramics. (4 cr; prereq upper div IT, 5011, 5101, 5102 or #; 1 lect, 1 rec hrs per wk) General introduction to ceramics, including glasses. Crystalline and non-crystalline structures, phase relations, ternary phase diagrams; mechanical, thermal, electrical, magnetic, and optical properties of ceramics.

MatS 5200. Optical and Electron Microscopy of Solids. (4 cr; prereq upper div IT, 3400 or #; 2 lect, 3 lab hrs per wk) Practical experience in materials and techniques of evaluation. Investigation of microstructure using optical metallography. Use of transmission electron microscopy, scanning electron microscopy, and elemental microanalysis for metallurgical material systems.

MatS 5202. X-Ray Structural Analysis. (4 cr; prereq upper div IT, 5011 or #; 1 lect, 5 lab hrs per wk) Geometry of crystals; properties and diffraction of X-rays; single crystal Laue methods and powder techniques; crystal structure determination; structure of polycrystals; single crystal orientation; crystal texture; precision lattice parameter measurements, chemical analysis; stress measurements, radiography.

MatS 5304. Failure Analysis. (4 cr; prereq 5012, AEM 3016 or #; 2 lect, 4 lab hrs per wk) Selected materials science and engineering topics such as embrittlement, wear, corrosion, integrated circuit breakdown, vibration, and fatigue. Analysis of failure using metallographic, electron microscopy, and microanalytical techniques.

MatS 5411. Materials Design. (4 cr; prereq sr MatS major, 5012, 5013, 5101, 5200; 3 lect, 1 rec hrs per wk) Mechanical and thermal processing with applications to forging, extrusion, rolling; advanced topics on heat treatment of steel, titanium, and aluminum alloys, and materials for micro-electronic applications. Materials selection bases on cost and design function.

MatS 5450. Corrosion and Electrochemistry of Corrosion. (4 cr; prereq upper div IT, 5101 or #; 3 lect, 2 hrs lab per wk) Electrochemical thermodynamics, Butler-Volmer equation, electrochemical kinetics, theory of corrosion, passivation, inhibition, forms of corrosion, environmental degradation of mechanical properties, cathodic and anodic protection.

MatS 5455. Electrochemical Engineering. (4 cr; ChEn 5455; prereq upper div IT or grad; 5101 or ChEn 5201 or #; 4 lect hrs per wk) Fundamentals of electrochemical engineering. Electrokinetics, thermodynamics of cells, practical and advance cells (batteries), fuel cells, electrosynthesis, and modern sensors.
MatS 5460. Oxidation of Metals. (4 cr; prereq upper div IT, 5102 or #; 3 lect, 1 rec hrs per wk)
Theory of high temperature oxidation of metals and alloys; oxidation in complex environments; practical applications and design criteria.

MatS 5470. Corrosion and Electrochemistry on Homogeneous and Heterogeneous Surfaces. (4 cr; prereq 5450 or 5460 or #; 3 lect, 1 rec hr per wk)

MatS 5481, 5482, 5483. Special Problems in Physical Metallurgy and Materials Science. (Cr and hrs ar; prereq sr standing)
Library or lab studies of scientific or engineering problems in physical metallurgy and materials science.

MatS 5500. Senior Design Project. (4 cr [2 cr in each of two qtrs]; prereq sr MatS major; individual or team project, meetings with assigned adviser)
Allows students to integrate total coursework and lab experience through independent study. Subject area contracted with faculty adviser of student’s choice. Term paper and oral presentation required.

MatS 5610. Polymer Chemistry. (3 cr; prereq upper div IT, Chem 3301 or Chem 3331 or #; 3 lect hrs per wk)
Polymer synthesis characterization. Polymerization types: free radical, condensation, ionic, coordination polymerization kinetics and reactors; molecular weight distribution and its characteristics; network formation; swelling.

MatS 5613. Polymer Laboratory. (2 cr; one 4-hr lab per wk)
Students synthesize polymers and characterize their molecular structure and properties. Experiments include anionic polymerization, free radical copolymerization, copolymerization ratio by IR, molecular size by SEC, crosslinking polymerization, solubility, swelling, crystallization kinetics, thermal transitions by DSC, viscoelasticity, rubber elasticity, tensile properties.

MatS 5620. Processing of Polymers and Their Composites. (4 cr; prereq heat transfer and fluid mechanics or #; 3 lect hrs per wk, 3-hr lab every other wk)
Polymer processing principles and applications: rheology of long chain molecules, flow in simple geometries, die design, mixing, thermal properties, heat transfer, and phase change. Thermoplastic operations—extrusion, forming, and molding. Thermoset operations—fiber and particulate reinforced composites.

MatS 5630. Polymer Physical Properties. (3 cr; prereq 3400 or 5011 or 5610 or Chem 5610 or #; 3 lect hrs per wk)
Polymer structure-property relations: characterization of structure and morphology of the crystalline and amorphous state. Crystallization kinetics, vitrification and the glass transition, diffusion, viscoelasticity, rubber elasticity, mechanical properties, failure, permeability, optical and electrical properties, polymer composites, effect of processing on properties. Selecting and designing polymers for end use applications.

MatS 5820. Thin Films and Interfaces of Microelectronic Materials. (3 cr; prereq 5013 or #; 3 lect hrs per wk)
Oxidation of Si; formation of interfaces, silicides, and multilayers; interface growth and morphology; thermodynamic and kinetic parameters of evolving interfaces; distribution of reaction products; fabrication of diffusion barriers; epitaxial overlayers; electrical and analytical techniques for characterization.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

MatS 8112. Solid-State Reactions
MatS 8210. Structure-Property Relationships: Mechanical and Microelectronic
MatS 8213, 8214. Electronic Properties of Materials
MatS 8311. Theories of Mechanical Behavior of Solids
MatS 8320. High-Temperature Properties of Materials
MatS 8401. Transformations in Alloys and Origins of Microstructure
MatS 8460. Oxidation of Metals
MatS 8470, 8471, 8472. Seminar: Materials Science and Engineering
MatS 8480, 8481, 8482. Selected Topics in Materials Science and Engineering
MatS 8520. Electron Diffraction and Electron Microscopy
MatS 8521. Topics in Electron Microscopy
MatS 8522. Advanced X-Ray Diffraction of Metals

Mathematics (Math)

Note: The School of Mathematics expects each student to have and use a scientific calculator. More powerful calculators are not usually required but are always permitted. Math courses listed as prerequisites must have been passed with a minimum grade of C. Students who ignore prerequisites may be asked to withdraw from the course.

Math 1001. Excursions in Mathematics. (See College of Liberal Arts Bulletin)
Math 1008. Trigonometry. (See College of Liberal Arts Bulletin)
Math 1031. College Algebra and Probability. (See College of Liberal Arts Bulletin)
COURSE DESCRIPTIONS

Math 1051. Precalculus I. (4 cr; §1008, §1031, §1111, §1151, §1201; prereq 3 yrs high school mathematics, placement exam or GC 0631 with a grade of C or better) Algebra, analytic geometry, and trigonometry beyond the usual coverage found in a three-year high school mathematics program. First of two courses (see 1151). Prepares students for the full calculus sequence. Not an acceptable prerequisite for 1131.

Math 1131. Finite Mathematics. (See College of Liberal Arts Bulletin)

Math 1142. Short Calculus. (See College of Liberal Arts Bulletin)

Math 1151. Precalculus II. (4 cr, §1008, §1111, §1201; prereq 3 yrs high school mathematics, placement exam or 1051 with a grade of C or better) Second of two courses (see 1051) in algebra, analytic geometry, and trigonometry. Prepares students for the full calculus sequence. Not an acceptable prerequisite for 1131.

Math 1251-1252. One-Variable Differential and Integral Calculus I-II. (4 cr each, §1142, §1211-1221, §1411H-1421H, §1451H-1452H; prereq 4 yrs high school mathematics including trigonometry or grade of C or better in 1151 or equiv; grade of C or better in 1251 required for 1252) Calculus of functions of one variable and related geometry and applications.

Math 1261. Calculus III. (4 cr, §1353; prereq 1252 or 1352 or equiv) Further topics in calculus: parametric curves, polar coordinates, power series, Taylor polynomial. Linear algebraic equations, Gaussian elimination, determinants. Applications.

Math 1268. Short Course: Introduction to Linear Algebra. (2 cr, §1261, §3221, §3142; prereq differential equations course) Matrices, Gaussian elimination, determinants. Course offers in isolation the linear algebra of Math 1261. Designed for transfer students who have already had a course in differential equations. Meets the first four weeks of the quarter concurrent with Math 3221.

Math 1351-1352-1353 Calculus: Concepts, Explorations, and Applications. (4 cr each, §1251 for 1351, §1252 for 1352, §1261 for 1353; prereq background in precalculus and geometry and visualization of functions and graphs, familiarity with graphing calculator recommended; grade of C or better required to continue sequence) Reformed approach to calculus: co-op learning/small groups, labs, projects. Technology and applications emphasized with interdisciplinary modules. 1351: Functions, differentiation. 1352: Antiderivatives, integration. 1353: Differential equations, parametric curves, series, basic linear algebra.

Math 1551H-1552H. Honors: One-Variable Differential and Integral Calculus I-II. (4 cr each, §1211-1221, §1251-1252, §1411-1142H; prereq consent of IT Honors Office, grade of C or better in 1551H required for 1552H) Honors-level treatment of calculus of functions of one variable and related geometry and applications, including infinite sequences and series.

Math 1553H-3551H-3552H. Honors: Linear and Nonlinear Analysis I-II-III. (4 cr each; some parts of this course may not be taken for credit by students with previous 3xxx Math courses—adviser approval required; prereq 1251-1252 or 1551H-1552H or equiv; grade of C or better required to continue in sequence) Four major topics distributed approximately as follows. 1553H: Vector geometry and linear algebra. 3551H: Ordinary differential equations. 3552H: Multivariable differential calculus. 3552H: Multivariable integral calculus. Taking courses in consecutive quarters recommended.

Math 1711H-1721H-1731H. Secondary Students Honors Calculus I-II-III. (4 cr per qtr; prereq # A) Accelerated honors sequence for selected mathematically talented high school students. Essentially the same as 1511H-1522H, plus applications to science and engineering. Emphasis on theory and computations.

Math 3001. Actuarial Science Seminar. (1 cr; prereq soph; S-N only) Actuarial science and related fields as careers. Lectures by practicing actuaries and others. Sample employment interviews at insurance or consulting companies.

Math 3066. Elementary Differential Equations. (4 cr, §3213, §3221, §3261, §3521; this course will not be taught; for info only) Elementary techniques of problem solving. First- and second-order equations, linear equations of higher order.

Math 3105-3106-3107 (formerly 1105-1106). Topics in Elementary Mathematics. (See College of Liberal Arts Bulletin)

Math 3142. Linear Algebra. (5 cr, §1241, §1261; prereq 1221 or 1252) Practical course in linear algebra, including vector spaces, matrices, determinants, linear algebraic equations and Gaussian elimination, basis and dimension, linear transformation, eigenvalues and eigenvectors, bilinear forms, diagonalization.

Math 3221. Introduction to Linear Algebra and Differential Equations. (5 cr, §1261, §3066, §3261, §3552H; prereq one yr calculus) Combines the linear algebra from Math 1261 with the major topics of Math 3261. For transfer students with one year of calculus. Students who have some linear algebra, or who have taken Math 1261 at this University, should take 3261 instead. Algebra part available separately as Math 1268.


Math 3252. Multivariable Integral Calculus. (4 cr, § for students with both 3311 and 3331, or both 3211 and 3331, §3551H, §3552H; prereq 3251 or §3251) Double and triple integrals; change of variable procedures, with emphasis on polar and spherical coordinates; mass and centroid; integration on curves and surfaces; vector fields and the Theorems of Green, Gauss, and Stokes.
Math 3261. Differential Equations With Linear Algebra. (4 cr, §3221, §3321, §3533H, §3551H; prereq one yr calculus [e.g., 1261 or 1353])
Differential equations, including first-order equations, linear equations with constant coefficients, and linear systems. Companion topics from linear algebra: general vector spaces, independence, spanning sets, basis, dimension, eigenvalues, eigenvectors.

Math 3262. Sequences, Series, and Foundations. (4 cr; prereq 1261)
Elements of logic; mathematical induction; the real number system; general, monotone, and recursively defined sequences; convergence; infinite series and convergence; Taylor’s series; power series with applications to differential equations; Newton’s method.

Math 3354-3355-3356. Calculus: Concepts, Explorations, and Applications. (4 cr each; prereq 1353 or background in one-variable calculus and the geometry and visualization of functions and graphs, grade of C or better required to continue in the sequence; familiarity with graphing calculator recommended)
Reformed approach to second-year calculus: small groups, labs, projects. Technology and applications featuring interdisciplinary modules. Functions, differentiation, parametrization of curves/surfaces; integration; differential equations; vector analysis; topics.

Math 3511H. Honors: Linear Analysis. (5 cr, §1261; prereq 1731H)
Continuation of Math 1731H, intended for selected mathematically talented high school students. Ideas and computations of linear algebra, including linear independence, linear transformations, matrices, and determinants. Students who complete this course may enter 3551H or any course for which 1261 is the prerequisite.

Math 3551H-3552H. Honors: Linear and Nonlinear Analysis II-III.
For description, see Math 1553H.

Math 5056. The Theory of Interest. (4 cr; prereq 1261 or equiv)
Time value of money. Accumulation function with compound interest as an important special case. Annuities, sinking funds, bonds, depreciation. Primarily for mathematics and business majors interested in actuarial science.

Math 5057-5058-5059. Actuarial Mathematics I-II-III. (4 cr each; prereq 5056, one qtr 5xxx-level probability or statistics such as 5679 or Stat 5131)
5057: Survival function; actuarial notation; actuarial present values for life insurance and life annuities; net premiums.
5058: Equivalence principle; reserves; multiple life functions and multiple decrement models; valuation of pensions. 5059: Further topics at instructor’s discretion.

Math 5105-5106-5107. Diversity in Mathematics. (4 cr, prereq 1021 or equiv or #1105, $3105 for 5105, §1106, $3106 for 5106, §3107 for 5107; for elem ed grads only)
Mathematical enrichment for elementary school instructors. Number theory (primes and congruences), fractions and decimals, regular and semi-regular polyhedra, map coloring, graph theory, game theory.

Math 5151. Elementary Set Theory. (4 cr; prereq 32xx math course or equiv or #)
Basic properties of operations on sets, cardinal numbers, simply ordered sets, well-ordered sets, ordinal numbers, axiom of choice, axiomatics.

Math 5152. Elementary Mathematical Logic. (4 cr, §5163; prereq 32xx math course or equiv or #)
Grammar and semantics of first and second-order languages; relational structures; a deductive system for first-order logic; completeness theorem; axiomatics of formal theories.

Math 5162-5163-5164. Mathematical Logic. (4 cr per qtr; prereq 1 yr calculus or equiv or Phil 5202 or #)
5162: Theory of computability; notion of algorithm, Turing machines, primitive recursive functions, recursive functions, Kleene Normal Form, Recursion Theorem. 5163: Provability and truth in formal systems: propositional and predicate logic, models of axiom systems, Goedel Completeness Theorem, nonstandard analysis. 5164: Goedel Incompleteness Theorem: decidable and undecidable theories, models of arithmetic.

Math 5209. Theory of Numbers. (4 cr; prereq 32xx math course or equiv or #)
Rigorous introduction to the elementary theory of numbers up to the classical results concerning congruences to a prime modulus (e.g., Fermat’s theorem). Usually covers one more advanced topic such as continued fractions, Gaussian integers, or quadratic reciprocity.

Math 5232-5233. Computer-Oriented Linear Algebra. (4 cr per qtr, §5242-5243, §5247, §5284; prereq 1261, 3261 or 3142 or equiv or #)
Linear transformations on finite dimensional vector spaces. Linear dependence, matrix algebra, inner products, orthogonality, and matrix inversion presented from algorithmic viewpoint, with students constructing and running illustrative computer programs. Eigenvalues and eigenvectors, Jordan canonical form, polar representation of linear transformations, determinants.

Math 5242-5243. Linear Algebra With Applications. (4 cr per qtr, §5232-5233, §5247, §5284; prereq 1261, 3261 or 3142 or equiv or #)
Systems of linear equations, finite dimensional linear spaces, bases, linear transformations, matrices, determinants, eigenvalues, reduction to canonical forms, quadratic and bilinear forms, applications.

Math 5245-5246-5247. Introduction to Modern Algebra I-II-II. (4 cr per qtr, §5262 for 5245, §5283 for 5246, §5284 for 5247; prereq three 32xx math courses or equiv or #)
Basic algebra course; a more concrete level than 5282-5283-5284. Group theory including normal subgroups, homomorphism, automorphism, the theorems of Lagrange and Cayley. Ring theory including ideals, integral domains, Euclidean rings, polynomial rings, and fields. Linear algebra including an abstract approach to vector spaces, and linear transformations and their structure.

Math 5282-5283-5284. Fundamental Structures of Algebra. (4 cr per qtr, §5245; prereq one soph sequence or # some previous abstract mathematics recommended)
Theory course, primarily for students planning mathematics graduate work. Group theory: normal subgroups, homomorphism, automorphism, the theorems of Lagrange, Cayley, and Sylow. Ring theory: rings, ideals, integral domains, Euclidean rings, polynomial rings, fields. Linear algebra: abstract approach to vector spaces, linear transformations; the theory of canonical forms, including the Jordan and rational.
Math 5331-5332-5333. Geometry I-II-III. (4 cr per qtr, 
§3161 for 5331, §5083 for 5332; prereq 1261 or equiv)
Advanced Euclidean geometry; axiomatic and analytic
hyperbolic geometry; projective geometry; symmetry and
geometric transformations and their connections with linear
algebra, group theory, and complex arithmetic; finite
geometries; convex geometrical figures.

Math 5337. Computational Methods in
Elementary Geometry. (2-4 cr; prereq multivariable
calculus [e.g., 3251] or #)
For preservice and in-service high school mathematics
teachers, as well as undergraduate mathematics majors
planning a career in secondary education. Modern
technological aids for teaching high school geometry.

Math 5341-5342. Introduction to Topology. (4 cr
per qtr; prereq one soph sequence or #; some previous
abstract mathematics recommended)
Set theory; axiom of choice, Zorn’s lemma. Metric spaces:
completeness, compactness, continuity. Basic point set
topology: countability and separation axioms, Urysohn’s
lemma, compactness, connectedness, product spaces.

Math 5343. Introduction to Algebraic Topology.
(4 cr; prereq 5342)
Classification of two-manifolds, fundamental group,
homology theory.

(4 cr per qtr; 5375: prereq 3252 or equiv or #; 5376:
prereq 3142 or 3261 or equiv, 5375)
Differential geometry. Curves and surfaces. Fundamentals
of vector analysis. Differential geometry. Advanced
theory of surfaces, integrals, geometry.

Math 5381-5382-5383. Introduction to
Computational Algebraic Geometry. (4 cr each;
prereq multivariable differential calculus [e.g., 1261,
3251])
Algebraic geometry. Geometry of curves and surfaces
defined by polynomial equations. Emphasis on computer
computation using algebraic geometry software, and on
the relations between geometry and algebra. Abstract
algebra presented as needed—no algebra prerequisite.

Math 5428. Mathematical Modeling. (4 cr; prereq
2 yrs elem calculus)
Methodology and practice in developing and analyzing
mathematical models of problems in physical, social,
and engineering sciences. Team approach to case studies.

Math 5457-5458-5459. Methods of Applied
Mathematics. (4 cr per qtr; prereq 3252, 3261 or
equiv)
Modern analytic tools used in applications of mathematics;
emphasis on technique. Linear algebra, ordinary and partial
differential equations, calculus of variations, Fourier series,
complex variables, optimization, numerical methods.

Math 5463-5464-5465. The Mathematics of
Industrial Problems. (4 cr; prereq 2 yrs calculus incl
3262 or equiv, familiarity with FORTRAN or PASCAL
or C, #)
Industrial problems such as crystal precipitation, air quality
modeling, color film developing, laser semiconductors.
Theoretical foundations and computational methods
involving ordinary and partial differential equations,
calculus of variations, and numerical analysis.

Math 5467. Introduction to the Mathematics of
Wavelets. (4 cr; prereq 2 yrs calculus or #)
Background theory and experience in wavelets. Inner
product spaces, operator theory, and Fourier transforms
applied to Gabor transforms, multi-scale analysis, discrete
wavelets, and self-similarity. Computing techniques.

Math 5473-5474-5475. Analysis of Numerical
Methods. (4 cr per qtr; 3252, 3261 or equiv; some
computer skills recommended)
Interpolation and approximation by polynomials. Solution
of linear and nonlinear systems of equations. Methods
solution of ordinary differential equations. Selected topics if
time permits.

Math 5477-5478-5479. Applied Numerical
Analysis of Partial Differential Equations. (4 cr;
prereq 5242 or equiv, 5513 or equiv, 5608 or equiv,
computer skills or #)
Numerical methods for partial differential equations of
linear and nonlinear elasticity, compressible and
incompressible fluid flow, multiphase flow, heat transfer,
and other selected systems of partial differential equations.

Math 5512. Differential Equations With
Applications. (4 cr; prereq 3261 or equiv)
Laplace transforms, series solutions, systems, numerical
methods, plane autonomous systems, stability.

Math 5514. Integral Equations. (4 cr; prereq 3261
or 5512 or equiv or #)
Integral equations; Fredholm formula, Neumann series.
Laplace transforms, successive approximations and
numerical methods. Relation of integral equations to systems
of linear algebraic equations and to differential equations.

Math 5521-5522-5523. Introduction to Ordinary
Differential Equations. (4 cr per qtr; prereq one
soph sequence or #)
5521: Existence and uniqueness theorems; successive
approximations; differential inequalities; linear systems;
fundamental matrix solutions; linear systems with constant
coefficients; variation of parameters. 5522: Phase plane
analysis; Poincaré-Bendixson theory; linear and nonlinear
oscillations; stability theory; asymptotic behavior of
solutions; control theory. 5523: Power series solutions,
majorant method; regular and irregular singular points; error
estimates, perturbation methods.

Math 5531-5532-5533. Dynamical Systems and
Chaos. (4 cr; prereq 1261-3251-3252-3261)
Introduction to dynamical systems theory with emphasis on
iteration of mappings of line, circle, and plane. Fixed points,
periodic points, stability, bifurcations, invariant Cantors
sets, rotation number, Smale horseshoe, fractal dimension.
Julia sets, Mandelbrot set, nonlinear oscillations, computer
experiments.

Math 5553H (formerly 3541H). Honors: Complex
Analysis and Related Topics. (4 cr, §§3331, §§5568;
prereq 3531H or 3552H)
Differntiation of complex-valued functions of a complex
variable; major theorems on analytic functions; power
series, Laurent series, other topics in sequences and series.
Math 5571. Fourier Series and Boundary Value Problems. (4 cr, §5571; prereq 3261 or equiv or #; 3262 recommended)

Math 5572. Elementary Theory of Complex Variables. (4 cr, §3541H, §5553H, §5572; prereq 3252 or equiv)

Math 5573. Laplace Transforms. (4 cr, §5573; prereq 5572)
Laplace transforms, Fourier transforms, inversion theorems; applications to differential equations.

Math 5574. Elementary Partial Differential Equations. (4 cr per qtr, §5568 for 5572-5573; prereq 5613 or §5608)

Math 5606-5607-5608. Advanced Calculus: A Rigorous Approach. (4 cr per qtr, §5612 for 5606, §5613 for 5607, §5614 for 5608; prereq 3252 or equiv; §3262 recommended)
Basic analysis course; a more concrete level than 5612-5613-5614. Foundations of analysis; completeness of the line, limits, convergence, continuity, integration. 5606-5607: Analysis on the line. 5608: Analysis in Euclidean space. Other topics at instructor’s discretion.

Math 5611. Advanced Calculus I. (4 cr; prereq linear algebra course)
Theory of real numbers; elements of point set theory; limits; differentiation; multivariable analysis.

Math 5612. Advanced Calculus II. (4 cr; prereq 3252, §3262; primarily for students planning graduate work in mathematics)
The Lagrange inversion formula.

Math 5632. Probability. (4 cr, §5681, §Stat 5131; prereq 3252 or equiv)
Elementary principles of probability, total and conditional probability, expectation, repeated trials, and topics chosen from the following: Stirling formula, the probability integral, geometrical probability, probability of causes, Bayes theorem, errors of observation, principle of least squares.

Math 5633. Introduction to Probability. (4 cr per qtr, §5679, §Stat 5131 for 5681; prereq 3252; §3262 recommended)
Logical development and various applications of probability. Probability spaces, random variables, central limit theorem; Markov chains.

Math 5701. Enumerative Combinatorics. (4 cr; prereq 3251 or equiv; 3xxx linear algebra course recommended)
Basic enumeration. Sets, permutations, distributions, partitions, generating functions (exponential and ordinary), recurrence relations, the method of inclusion-exclusion, and Polya theory.

Math 5702. Graph Theory and Optimization. (4 cr; prereq 3251 or equiv; 3xxx linear algebra course recommended)
Basic concepts in graph theory. Connectedness, Hamiltonian and Eulerian paths, trees, coloring, and matchings. Topics in optimization: networks, flows, spanning trees, and graph algorithms. Definitions and examples of designs, Latin squares, and codes.

Math 5703. Constructive Combinatorics. (4 cr; prereq 5701, knowledge of some programming language)
Algorithmic and bijective approaches to permutations, subsets, trees, tableaux, and partitions, ranking and unranking algorithms. Connections with generating functions. The Lagrange inversion formula.

Math 5711. Linear Programming and Applications. (4 cr; prereq linear algebra course)
Geometry of linear programming, interpreting solutions to linear programs. Simplex method; connections to geometry; duality theory; sensitivity analysis; applications to cutting stock, allocation of resources, and scheduling problems; Dantzig-Wolfe decomposition; interior methods.

Math 5712. Combinatorial Optimization. (4 cr; prereq 5711)
Graph algorithms and integer programming techniques. Flows; matching and transportation problems; spanning trees, distance in graphs; branch and bound; cutting planes; heuristics; applications to traveling salesman and knapsack problems.

Math 5900. Tutorial Course in Advanced Mathematics. (Cr ar; prereq #)
Qualified students whose needs are not met by courses offered may make arrangements to study content of other courses.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

Math 8140-8141-8142. Applied Logic
Math 8166-8167-8168. Recursion Theory
Math 8190-8191-8192. Topics in Logic
Math 8200-8201-8202. General Algebra
Math 8203-8204-8205. Algebraic Geometry
Math 8206-8207-8208. Algebraic Number Theory
Math 8209-9210. Homological Algebra
Math 8211-8212. Commutative Algebra
Math 8250-8251-8252. Topics in Group Theory
Math 8263-8264-8265. Topics in Algebraic Geometry
COURSE DESCRIPTIONS

Math 8266-8267-8268. Topics in Number Theory
Math 8270-8271-8272. Lie Groups and Lie Algebras
Math 8290-8291-8292. Topics in Algebra
Math 8300-8301-8302. Manifolds/Topology
Math 8306-8307-8308. Algebraic Topology
Math 8330-8331-8332. Differential Topology
Math 8342-8343-8344. Topological Dynamics
Math 8365-8366-8367. Riemannian Geometry
Math 8370-8371-8372. Topics in Geometry
Math 8380-8381-8382. Topics in Advanced Differential Geometry
Math 8406-8407-8408. Advanced Methods of Applied Mathematics
Math 8430-8431-8432. Mathematical Theory of Fluid Dynamics
Math 8450-8451-8452. Topics in Numerical Analysis
Math 8460-8461-8462. Mathematical Problems in Theoretical Physics
Math 8480-8481-8482. Selected Topics of Celestial Mechanics
Math 8500-8501-8502. Theory of Ordinary Differential Equations
Math 8540. Topics in Differential and Difference Equations
Math 8550-8551-8552. Theory of Partial Differential Equations
Math 8560-8561-8562. Calculus of Variations and Minimal Surfaces
Math 8570-8571-8572. Infinite Dimensional Dynamical Systems
Math 8590-8591-8592. Topics in Partial Differential Equations
Math 8600-8601-8602. Real Analysis
Math 8620-8621-8622. Theory of Singular Integrals
Math 8640-8641-8642. Topics in Real Analysis
Math 8650-8651-8652. Theory of Probability
Math 8653-8654. Introduction to Stochastic Processes
Math 8656-8657-8658. Measure Theory and Probability
Math 8668-8669-8670. Introduction to Combinatorial Theory
Math 8672, 8673, 8674. Topics in Combinatorial Theory
Math 8690-8691-8692. Topics in the Theory of Probability
Math 8700-8701-8702. Complex Analysis
Math 8790-8791-8792. Topics in the Theory of Analytic Functions
Math 8800-8801-8802. Functional Analysis
Math 8990-8991-8992. Reading and Research

Mechanical Engineering (ME)

Many of the courses listed below have honors sections available. Contact the Student Advising and Information Office, 121 Mechanical Engineering (612/625-5842) for more information.

ME 1001. Introduction to Mechanical Engineering. (1 cr; S-N only; 1 lect hr per wk)
Introduction to the field presented by practicing engineers and faculty. Topics include the mechanical engineering curriculum, the elective program, the profession, and related areas of research.

ME 1010-1012. Introduction to Engineering I-II. (4 cr; prereq lower div IT, 1010 for 1012)
Design, prototyping, shop skills, use of computer packages, and visual, oral, and written communication. Team and individual projects include reverse engineering of existing products and creative design and fabrication of new ideas and products.

ME 1025. Engineering Graphics. (4 cr; prereq IT student, Math 1251 or equiv; 3 lect, 1 rec hrs per wk, open lab hrs)
Engineering representation in pictorial view and multiview; sketching techniques, size description, standard and simplified practices applied to graphical communication. Analysis of systems of projection; correlation of graphical, numerical, and computer solutions of space problems, intersections and development. Methods of computer-aided graphics.

ME 1025. Engineering Graphics. (4 cr; prereq IT student, Math 1251 or equiv; 3 lect, 1 rec hrs per wk, open lab hrs)
Engineering representation in pictorial view and multiview; sketching techniques, size description, standard and simplified practices applied to graphical communication. Analysis of systems of projection; correlation of graphical, numerical, and computer solutions of space problems, intersections and development. Methods of computer-aided graphics.

ME 3020. Mechanical Engineering Computation. (4 cr; prereq IT student, Math 3261 or equiv, CSci 3101; 3 lect, 1 lab-rec hrs per wk)

ME 3201. Mechanical Engineering Systems Analysis. (4 cr; prereq IT student, Math 3261 or equiv; 3 lect, 2 lab hrs per wk)
Determination of response of engineering systems using transfer function representation. Analogies between engineering systems based on transfer function equivalence.
ME 3203. Analysis of Mechanism Systems. (4 cr; prereq upper div ME, 3020, AEM 3036 or equiv; 3 lect, 1 rec-lab hrs per wk)
Diagnostics of the performance of mechanism systems involving linkage, hydraulic, pneumatic, and electromechanical components. Energy balance techniques used to describe energy flow through machine systems.

ME 3205. Engineering Systems Design. (4 cr; prereq upper div ME, AEM 3016; 3 lect, 2 lab hrs per wk)

ME 3301. Thermodynamics. (4 cr; prereq IT or forest product student, Chem 1014 or Chem 1052 or Phys 1252, Math 3261 or equiv; 4 lect hrs per wk)

ME 3303. Applied Thermodynamics. (4 cr, §3305; prereq upper div ME or AEM, 3301 or equiv; 4 lect hrs per wk)
Application of laws of thermodynamics to chemically reacting systems and engineering systems. Vapor cycles, gas engine cycles, propulsion systems, refrigeration and air-water vapor mixtures.

ME 3701-3702. Basic Measurements Laboratory I-II. (2 cr per qtr; prereq upper div ME, 3301 or §3301 for 3701, 3701 for 3702; 1 lect, 3 lab hrs per wk)
Treatment of experimental data, analysis and study of experimental systems via the computer. Static and dynamic characteristics of measurement systems. Fundamental principles of measurement and calibration. Measurement of temperature, pressure, vacuum, humidity, density, viscosity, heating values, speed, power, force, stress-strain, and radioactivity.

ME 3741-3742-3743 I. Industrial Assignment. (2 cr per qtr; prereq ME undergrad, regis in ME co-op program for 3741, 3741 for 3742, 3742 for 3743)
Industrial work assignment in mechanical engineering intern program. Evaluation based on student’s formal written report covering the quarter’s work assignment.

ME 3900. Introduction to Engineering Statistics. (4 cr; prereq IT student, Math 1261 or equiv; 3 lect, 1 rec hrs per wk)
Elements of probability, descriptive statistics, binomial and Poisson distributions; normal distribution, estimation, hypothesis testing, regression analysis and analysis of variance.

ME 5190. Advanced Engineering Problems. (2-4 cr; prereq submission of approved dept permission form; open to upper div students)
Special investigations in various fields of mechanical engineering and related areas including an independent study project.

ME 5203. Advanced Analysis and Synthesis of Mechanism Systems. (3-4 cr; prereq IT or grad student, 3203 or equiv; computer programming desirable; 3 lect hrs per wk)
Analytical methods of kinematic, dynamic, and kineto-elastic-dynamic analysis and synthesis of mechanisms. Computerized design for function, path and motion generation based on Burmester theory.

ME 5207. Experimental Stress Analysis. (4 cr; prereq upper div IT or grad, AEM 3016; 3 lect, 3 lab hrs per wk)

ME 5209. Friction and Lubrication. (3-4 cr [1-cr term paper option]; prereq IT or grad student, AEM 3200 or CE 3400 or equiv; 3 lect hrs per wk)
Solid friction mechanism and boundary lubrication. Hydrodynamic and hydrostatic lubrication theory applied to bearing design. Introduction to gas bearings.

ME 5220. Computer-Aided Design, Optimization, and Computer Graphics. (4 cr; prereq IT or grad student, 1025, 3030, 3203, 3205; 3 lect, 1 rec hrs per wk)
Application of computer-aided engineering to mechanical design. Engineering design projects and case studies using computer-aided design software, design optimization, and computer graphical presentation of results.

ME 5225. Finite Elements in Mechanical Design. (4 cr; prereq IT or grad student, 3205, 5342, programming; offered UC spring qtr)
Introduction to fundamentals of finite element analysis, oriented to mechanical engineering design applications. Extensive examples from industry and student projects involving actual set-up and solution of descriptive problems using industry-accepted analysis codes and interactive graphics for model generation.

ME 5226. Finite Element Methods in Mechanical Engineering I. (4 cr; prereq upper div IT or grad student, 3020, AEM 3016, Math 3261, FORTRAN programming)
Introduction to computational methods, direct stiffness approach, introduction to elasticity and energy methods. Interpolation, development of simple finite elements, assembling, solution methods. Programming considerations and design application.

ME 5227. Finite Element Methods in Mechanical Engineering II. (4 cr; prereq upper div IT or grad student, 5226 or #, programming)
Fundamental concepts of FEM; variational and weighted residual methods; interpolation functions; linear/higher order elements; methodology and formulation for one-end two-dimensional problems in structural mechanics and heat transfer; axisymmetric problems; solution schemes for linear-nonlinear static/steady-state models; computer implementation.

ME 5230. Acoustics and Vibration Laboratory. (2 cr; prereq upper div ME, 3201, 3701, 3702)
Transducers and signal conditioning for acoustic and vibration measurement; sinusoidal, impulse, and stochastic identification techniques; modal analyzers, comparison of analytical and experimental modal results.
ME 5231. Mechatronics Laboratory. (2 cr; prereq upper div ME, 3201, 3701, 3702)
Computer control of servomechanisms; motor and mechanical drive component types and selection; power electronics; microprocessors and programmable controllers; digital control; position, force, and velocity measurement; performance prediction and testing techniques.

ME 5233. Programmable Automation. (2 cr; prereq upper div ME, 3702)
Programmable logic controllers, machine tool and robot controllers and factory automation networks. Programming methods for PLCs. Group project to design a controller for a flexibly automated multi-station assembly or fabrication cell.

ME 5244. Vibration Engineering. (4 cr; prereq IT or grad student, 3201 or equiv; 4 lect hrs per wk)
Applications of the theory of vibration to the design and optimization of isolators, detuning mechanism, viscoelastic suspensions and structures.

ME 5254. Design Morphology With Applications. (4 cr; prereq upper div ME; completion of (3201, 3203, 3205), [3303, 5342] or #; 1 lect, 7 lab hrs per wk)
Detailed study of design problem formulation and the structure of the open-ended solution process based on design morphology. Case studies and student projects as instructional vehicles.

ME 5255. Engineering Design Project. (4 cr [may be repeated for cr]; prereq upper div ME, 5254; 1 lect, 7 lab hrs per wk)
Participation in solution of systems design problems that have developed criteria, order-of-magnitude evaluation of alternatives, and generation of preliminary design.

ME 5260. Engineering Materials and Processing. (4 cr; prereq upper div ME, 3020, AEM 3016, Chem 1052, MatS 3400, Phys 1253; 3 lect, 1 rec hrs per wk; safety glasses required)
Introduction to materials and processing including physical and metallurgical properties, consolidation, etc. Material processing including machining, welding, and deformation processes.

ME 5262. Material Working and Fabrication Processes. (4 cr; prereq IT or grad student, 5260 or equiv; 3 lect, 1 rec hrs per wk)
Theory and application of joining techniques, welding, brazing, and adhesive bonding. Metal forming, rolling, swaging, drawing, and similar operations. Inspection and test methods to control and evaluate fabrication processes including X-ray, magnetic, metallographic, and chemical methods.

ME 5264. Material Consolidation Processes. (4 cr; prereq IT or grad student, 5260 or equiv; 3 lect, 1 rec hrs per wk)
Theory and practice of material consolidation including casting and powder metal processes. Composite materials techniques.

ME 5265. Computer-Assisted Product Realization. (4 cr, prereq IT or grad student, 5260 or equiv, engineering computer language course; 2 lect, 6 lab hrs per wk)
Integration of computer-based engineering, design, and manufacture to reduce concept-to-product cycle time. Course requires planning and execution of a product and process design to fulfill functional requirements using software tools. Team project to instill appreciation of issues in integration of design and manufacture.

ME 5268. Properties and Fabrication of Plastics. (4 cr; prereq IT or grad student, 5260 or equiv; 3 lect, 1 lab-rec hrs per wk)

ME 5270. Materials—Design Requirements. (4 cr; prereq IT or grad student, 5260 or equiv; 3 lect, 1 rec hrs per wk)
Fundamental properties of engineering materials including fabrication, treatment, physical and corrosive properties. Failure mechanism, cost and value analysis as related to material selection and specification.

ME 5271. Robotics. (3-5 cr [2-cred lab option]; prereq IT or grad student, 5283 or equiv)

ME 5272. Non-Contact Sensing. (3-5 cr [2-cred lab option]; prereq IT or grad student, 5283 or equiv)
Optical and acoustic-based sensing for inspection measurement and closed-loop control. Mathematics of image processing as used in sensors. Inspection, part classification, tracking, ranging. Lab projects.

ME 5275. Computer-Controlled Experimentation. (4 cr; prereq IT or grad student, 5283 or equiv; 3 lect, 2 lab-rec hrs per wk)
A/D and D/A conversion, Sampling Theorem DFT and FFT, analog and digital filter design, simulation, real-time micro- and minicomputer control.

ME 5283. Industrial Instrumentation and Automatic Control. (4 cr; prereq IT or grad student, 3201 or equiv; 4 lect hrs per wk)

ME 5284. Control Systems. (4 cr; prereq IT or grad student, 5283 or equiv; 4 lect hrs per wk)

ME 5285. Control Systems Laboratory. (2 cr; prereq IT or grad IT major, 5283 or equiv)
Experiments designed to illustrate and apply control theory to mechanical engineering systems. Measurement techniques, calibration, timing of controls, characterization of sensors and control circuits.

ME 5288. Modeling and Simulation of Dynamic Systems. (4 cr; prereq IT or grad student, 5283 or equiv; 3 lect, 1 lab hrs per wk)
Generalized approach to developing models for describing complex dynamic interactions between mechanical, electrical, fluid, and thermal systems. Analog and digital simulation. Applications to electromechanical devices, transducers, hydraulic power and thermofluid systems.
ME 5342. Heat Transfer. (4 cr; prereq upper div IT or wood and paper science or grad student, 3301, AEM 3200 or CE 3400; 4 lect hrs per wk)
Steady and unsteady conduction of heat. Convection heat transfer in boundary layer and duct flows; forced and free convection; condensation and boiling; heat exchangers. Heat transfer by thermal radiation; radiative properties of black bodies and real surfaces.

ME 5343. Introduction to Thermal Design. (4 cr, prereq upper div IT or grad student, 5342, 5254 or equiv; 4 lect hrs per wk)
Elements of thermal design. Developments of design philosophy and governing relations for thermal configurations, including barriers and enclosures, longitudinal, radial and pin-fins, longitudinal fin arrays. Case studies from diverse thermal application areas, e.g., furnaces and ovens, HVAC systems, solar energy use, electronic equipment.

ME 5344. Thermodynamics of Fluid Flow. (4 cr, §AEM 5201; prereq IT or grad student, AEM 3200 or CE 3400; 4 lect hrs per wk)
Compressible flow of gases in engineering systems such as nozzles, ducts, combustion chambers, ramjets, pipelines. Isentropic flow in variable area passages. One-dimensional discontinuities. Flow with wall friction, heat transfer, and mass transfer.

ME 5345. Heat Transfer in Electronic Equipment. (4 cr; prereq IT or grad student, 5342; 3 lect, 1 rec hrs per wk)
Development and application of analytical models of thermal phenomena occurring in electronic equipment. Thermal characteristics and thermal failure modes of microelectronics components. Packaging configurations used for various microelectronic applications.

ME 5346. Intermediate Heat Transfer. (4 cr; prereq upper div IT or grad student, 5342; 4 lect hrs per wk)

ME 5351. Computational Heat Transfer. (4 cr; prereq IT or grad student, 5342)
Numerical solution of heat conduction and duct flow. Use of a computer program to solve complex problems involving steady and unsteady conduction, fully developed flow and heat transfer in ducts, and other special applications. Case studies to illustrate design optimization.

ME 5360. Plasma-Aided Manufacturing. (4 cr; prereq upper div IT or grad student, 3301, 5342 or equiv; 3 lect, 2 rec hrs per wk)
Introduction to plasmas as a manufacturing tool. Welding and plasma spraying. Instructions from design and thermal sciences supplemented by industry practitioners.

ME 5370 (formerly 5330, 5433). Transport Phenomena Laboratory. (4 cr; prereq upper div ME, 3303, 3701, 3702, AEM 3200 or CE 3400, CE 5342)
Measurement and analysis of heat transfer in single phase, thermal/fluid systems as well as the statistical design of experiments. Fundamentals of mass transfer and heat exchanger design.

ME 5442. Vapor Cycle Power Systems. (4-5 cr [1-cr term paper option]; prereq IT or grad student, 3303; 4 lect hrs per wk)
Vapor cycle analysis, regeneration, reheat, compound cycle modifications, combined gas turbines vapor cycle systems and binary systems. Combustion problems, solar, nuclear, and unusual energy sources for space power systems. A variety of configurations are evaluated using a steam cycle computer code.

ME 5443. Turbomachinery. (4-5 cr [1- or 2-cr term paper option]; prereq IT or grad student, 3301 or equiv; 3 lect hrs per wk)
Thermodynamic analysis of energy transfer between fluid and rotor; dimensional analysis; principles of axial, mixed, and radial flow pumps, fans, compressors and turbines; cascade performance; computer flow simulations; applications to propulsion systems and power plants.

ME 5446. An Introduction to Combustion. (4 cr; prereq IT or grad student, 5342 or equiv; 4 lect hrs per wk)
Flame propagation, quenching and ignition in a gaseous mixture; combustion of solid and liquid particles, and gaseous jets. Applications to selected propulsion systems.

ME 5455. Rocket Propulsion. (3-5 cr [1- or 2-cr term paper option]; prereq IT or grad student, 3303 or equiv; 3 lect hrs per wk)
Mode of operation and performance limitations of chemical rockets with liquid, solid, and free radical propellants, nuclear and solar rockets with thermal and electromagnetic propellant acceleration.

ME 5460. Internal Combustion Engines. (4 cr; prereq IT or grad student, 3301 or equiv; 4 lect hrs per wk)
Principles of power production, fuel consumption, and emissions of gasoline and diesel engines; fuel-air cycle analysis, combustion flames, knock phenomena, air flow and volumetric efficiency, mixture requirements, ignition requirements and performance.

ME 5461. Internal Combustion Engine Modeling. (4-5 cr [1-cr term paper option]; prereq IT or grad student, 5460 or equiv; 4 lect hrs per wk)
Traditional alternate fuels; engine lubrication and friction; engine emissions and measurement techniques; turbocharging, heat transfer and cooling; computer-based cycle modeling.

ME 5462. Gas Turbines. (4 cr; prereq IT or grad student, 3301 or equiv; 4 lect hrs per wk)

ME 5470 (formerly 5430, 5432, 5433). Energy Conversion Systems Laboratory. (4 cr; prereq upper div ME, 3303, 3701, 3702, AEM 3200 or CE 3400)
Experimental and analytical examination of the thermochemistry and fluid mechanics of various energy conversion systems, including internal combustion engines, cogeneration systems, axial flow compressors and turbines, and Rankine cycles. Students do significant experimental design using statistical means.
ME 5480. Biological Fluid Flow. (3-4 cr; [1-cr term paper option]; prereq IT or grad student, CE 3400, AEM 3200 or equiv; 3 lect hrs per wk) Rheology and fluid dynamics of biological fluids. Blood flow, biological pumping, self-propelled particles, unusual viscoelastic behavior of biological fluids, and other fluid motions.

ME 5603. Thermal Environmental Engineering. (4 cr; prereq IT or grad student, 3303, 5342 or equiv; 4 lect hrs per wk) Thermodynamic properties of moist air; psychrometric chart applications; solar radiation; heat and moisture transmission through structures; human thermal comfort and indoor air quality; heating, cooling and ventilating systems and controls.

ME 5604. Heating and Cooling Loads in Buildings. (4 cr; prereq 5603; 4 lect hrs per wk) Transient heat transfer through structures; lighting and other internal gains; ventilation; winter and summer loads; seasonal energy estimation methods; computer simulation programs; codes and standards.

ME 5605. Refrigeration and Air Conditioning Systems. (4 cr; prereq IT or grad student, 3303; 4 lect hrs per wk) Vapor compression and absorption refrigeration systems; heat pumps; heat exchangers; piping and duct layout and sizing; operations and control of building air conditioning systems.

ME 5609. Air Pollution. (4 cr; prereq upper div IT or grad student; 4 lect hrs per wk) Air pollution sources, atmospheric transport, transformations and fate. Air pollution meteorology, dispersion, and models. Basic chemistry of secondary pollutant formation, aerosol growth, air pollutant visibility relationships. Standards and regulations.

ME 5610. Air Pollution Control. (4 cr; prereq IT or grad student, 3303; 4 lect hrs per wk) Study of control devices and techniques for gases and particulate emissions from stationary and mobile sources. Topics include cyclones, electrostatic precipitators, bag houses, wet and dry scrubbers, combustion modification, and alternate fuels.

ME 5613. Principles of Particle Technology. (4 cr; prereq IT or grad student, 3303; 4 lect hrs per wk) Definition, theory, and measurement of particle properties, particle statistics, fluid dynamics, optical, electrical, and thermal behavior of particles.

ME 5614. Principles of Particle Technology. (4 cr; prereq IT or grad student, 5613; 4 lect hrs per wk) Gas cleaning, particle transport, comminution, classification, surface properties, packed beds, powder behavior, and miscellaneous topics.

ME 5616. Aerosol Measurement. (2 cr; prereq IT or grad student, 5613, 5614 or #; 3 lect-lab hrs per wk) Principles of aerosol measurement. Modern aerosol instrumentation. Topics include optical techniques; inertial collectors; electrical mobility techniques; Beta attenuation; and piezoelectric mass sensing techniques, condensation nuclei counters, and diffusion batteries.


ME 5620. Clean Room Technology and Particle Monitoring. (4 cr; prereq IT or grad student, 3303 or #; 3 lect, 2 lab hrs per wk) Fundamentals of clean room technology for microelectronics manufacturing; particle mechanics and filtration; filter performance and testing; airborne and liquidborne particulate contaminates; optical particle counters, condensation nucleus counter and wafer surface scanner; clean room design and operation; exhaust ventilation; high purity gas and water supply systems.

ME 5630. Thermal Environmental Engineering Senior Laboratory. (2 cr; prereq upper div ME, 3701, 3702, 5603 or #5603) Experiments in psychrometrics, refrigeration, air conditioning, solar energy, and other topics related to refrigeration and building heating and cooling.

ME 5712. Solar Energy Utilization. (4 cr; prereq IT or grad student, 3303, 5342; 4 lect hrs per wk) History and potential of solar energy use; availability of solar radiation on clear and cloudy days; incident radiation on horizontal, vertical, and inclined surfaces; flat-plate and concentrating solar collectors; heating and cooling with solar energy; power generation; review of current research.

ME 5741-5742!. Industrial Assignment and Design Project. (4 cr per qtr; prereq 3742 for 5741, 5741 for 5742) Solution of system design problems that require development of criteria, evaluation of alternatives, and generation of a preliminary design. Final report emphasizes design communication and describes design decision process, analysis, and final recommendations.

ME 5990. Topics in Mechanical Engineering. (4 cr [may be repeated for cr]; prereq upper div IT or grad student, submission of permission form, #) Specialized topics within various areas of mechanical engineering. Emphasis on topics of current interest. Topics vary quarterly.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

ME 8190. Mechanical Engineering Graduate Seminar

ME 8203. Advanced Planar Linkage Synthesis

ME 8226. Finite Element Methods for Nonlinear/Linear Transient Dynamic Problems

ME 8227. The Finite Element Method in Metal Forming Processes

ME 8243. Photoelasticity
ME 8250-8251-8252. New Product Design and Development
ME 8280. Multivariable Control Systems I
ME 8281. Multivariable Control Systems II
ME 8310. Advanced Thermodynamics
ME 8311. Statistical and Nonequilibrium Thermodynamics
ME 8326. Boiling Heat Transfer and Multiphase Flow
ME 8330. Conduction
ME 8331. Convection
ME 8332. Radiation
ME 8334. Turbulent Convection
ME 8351. Computation of Fluid Flow and Heat Transfer
ME 8352. Advanced Computation of Fluid Flow and Heat Transfer
ME 8360-8361-8362. Introduction to Plasma Technology
ME 8370. Experimental Methods in Heat Transfer
ME 8372. Optical Diagnostics of Flow Systems
ME 8379. Thermal Sciences Graduate Seminar
ME 8443. Applied Thermodynamics I
ME 8444. Applied Thermodynamics II
ME 8445. Applied Thermodynamics III
ME 8613. Fundamentals of Aerosol Behavior
ME 8701-8702. Design Studies in Engineering I-II
ME 8770-8771-8772. Mechanical Engineering Research
ME 8773-8774-8775. Graduate Seminar
ME 8800. Modern Development in Mechanical Engineering

Physics (Phys)

Phys 1001f, w, s, su. Introductory Physics. (5 cr per qtr; prereq high school algebra and plane geometry; trigonometry recommended; 4 lect, 1 rec, 2 lab hrs per wk)
- Lectures, recitation, and lab sessions. Primarily for students interested in topics useful in technical areas. Fundamental principles of physics in context of the everyday world. Use of kinematics, dynamics, and conservation principles with quantitative and qualitative problem-solving techniques to understand phenomena of mechanics, electromagnetism, and the structure of matter.

Phys 1041f, w, su, UC-1042w, s, su, UC. Introductory Physics. (5 cr per qtr; prereq high school algebra and plane geometry; trigonometry recommended; 4 lect, 1 rec, 2 lab hrs per wk)
- Lectures, recitation, and lab sessions. Primarily for students interested in topics useful in technical areas. Fundamental principles of physics in context of the everyday world. Use of kinematics, dynamics, and conservation principles with quantitative and qualitative problem-solving techniques to understand phenomena of mechanics, electromagnetism, and the structure of matter.

Phys 1104f-1105w-1106s. General Physics. (4 cr per qtr [no cr for IT students]; prereq high school calculus or Math 1142 or equiv, high school trigonometry or Math 1008 or Math 1151, ¥1107 for 1104, ¥1108 for 1105, ¥1109 for 1106; 4 lect, 1 quiz hrs per wk)

Phys 1107f-1108w-1109s. General Physics Laboratory. (1 cr per qtr; prereq ¥1104 for 1107, ¥1105 for 1108, ¥1106 for 1109 or #; 2 lab hrs per wk)
- Lab exercises.

Phys 1251f, w, su, -1252w, s, su, -1253f, s, su, -3254f, w. General Physics I-IV. (4 cr per qtr; §1254, §1451H-1452H-1453H-1454H; prereq Math 1251 or ¥Math 1251 for 1251, Math 1252 or ¥Math 1252 for 1252, Math 1261 or ¥Math 1261 for 1253; 1 quiz hr as needed, 3 lect, 1 rec, 2 lab hrs per wk for 1251, 1252, 1253 and 4 lect hrs per wk for 3254)

Phys 1451Hf-1452Hw-1453Hs-3454H (formerly 1411H-1421H-1431H-1441H). Honors Physics I-IV. (4 cr per qtr; §1251-1252-1253-1254/3254, §1454H; prereq selection for IT honors curriculum or consent of IT Honors Office; 3 lect, 1 rec, 2 lab hrs per wk)
- Comprehensive calculus-level general physics course for honors students. Newtonian principles of mechanics, electromagnetic forces and fields, introduction to 20th-century physics, thermal and other properties of matter.

Phys 1911-1912f. Laboratory-Based Physics for Teachers. (4 cr per qtr [no cr for IT students]; 6 lab hrs per wk)
- For students intending to be elementary education majors.
- Topics applied to elementary school curriculum include the Earth’s motion, properties of matter, heat and temperature, kinematics, and electric current.

Phys 3501. Modern Physics. (4 cr [no cr for physics majors]; §3512-3513; prereq 1253 or 1453, Chem 1052, Math 3261)
- Elementary quantum physics with examples from thermal radiation, atomic and molecular structure, and solid-state physics.
Phys 3512w-3513s. Quantum Physics I-II. (3 cr per qtr; prereq 1253 or 1291 or 1441 or 1453, Math 3261 or Math 3261; 1254, 3254 or 1454 or 3454 recommended; 3 lect hrs per wk)
Introduction to quantum mechanics and selected topics form its application to atomic, molecular, condensed-matter, nuclear, elementary-particle, and statistical physics. Associated labs are 3512-3513.

Phys 3515w, 3516s. Modern Physics Laboratory. (2 cr; prereq 3512 or 3501 or 3502 or 3501; 1 lect, 3 lab hrs per wk)
Lab experiments in atomic, solid-state, and nuclear physics offered in conjunction with 3512-3513.

Phys 3601f. Special Relativity. (3 cr; prereq 1253 or 1453; 3 class hrs per wk)
Introduction to special relativity.

Phys 3970. Directed Studies. (1-5 cr per qtr; prereq #, A)
Independent, directed study in physics in areas arranged by the student and a faculty member.

Phys 5021f-5022w. Introduction to Analytic Mechanics. (4 cr per qtr; prereq Math 3261 or equiv; 4 lect hrs per wk)
Analytical course in Newtonian mechanics. Mathematics beyond the prerequisites developed as required.

Phys 5023s-5024f. Introduction to Electric and Magnetic Fields. (4 cr per qtr; prereq Math 3261 or equiv; 4 lect hrs per wk)
Classical theory of electromagnetic fields using vector algebra and vector calculus.

Phys 5031f-5032w-5033s. Topics in Mathematical Physics. (4 cr per qtr; prereq two 5xxx math courses; 4 lect hrs per wk)
Mathematical techniques for physics. Application of mathematical methods to physical problems.

Phys 5051f-5052w-5053s. Classical Physics. (4 cr per qtr; prereq 5022, 5024, advanced calculus or #; 4 lect hrs per wk)
Classical mechanics, special relativity, and classical electrodynamics. Applications of advanced mathematical techniques.

Phys 5061f. Computational Methods in the Physical Sciences I. (4 cr, §Ast 5061; prereq upper div or grad status or #; 2 lect, 6 lab hrs per wk)
Problem solving in the physical sciences with computer programs. Numerical methods; mapping problems onto computational algorithms. Arranged lab at scientific computer workstation.

Phys 5062w. Computational Methods in the Physical Sciences II. (4 cr, §Ast 5062; prereq 5061 or Ast 5061 or #; 2 lect, 6 lab hrs per wk)
Advanced techniques in computer simulation; examples from classical statistical mechanics, classical electrodynamics, and fluid dynamics. Computer experiments illustrating these techniques with graphics.

Phys 5101f-5102w. Introduction to Quantum Mechanics. (4 cr per qtr; prereq 3513; 4 lect hrs per wk)
Mathematical techniques of quantum mechanics. Schrödinger equation and simple applications, general structure of wave mechanics, operator methods, perturbation theory, radiation of atoms.

Phys 5121f. Methods of Experimental Physics I. (5 cr; prereq 3516 or equiv lab exper or #; 3 lect, 4 lab hrs per wk)
Contemporary experimental techniques. Introduction to modern analog and digital electronics from an experimental viewpoint.

Phys 5122w. Methods of Experimental Physics II. (4 cr; prereq 5121 or #; 2 lect, 6 lab hrs per wk)
Contemporary experimental techniques. Use of computers for data acquisition and experimental control. Experiments with data analysis.

Phys 5123s. Methods of Experimental Physics III. (4 cr; prereq 5122 or #; 2 lect, 6 lab hrs per wk)
Contemporary experimental techniques. Students design and execute an experimental project. Lectures on specialized topics emphasizing research labs.

Phys 5124. Experimental Project. (Cr ar; prereq 5123, #)
Research project in a physics area of contemporary interest. Project must be approved by faculty coordinator before registration.

Phys 5151f-5152w-5153s. Quantum Mechanics. (4 cr per qtr; prereq 5102 or equiv, advanced calculus or #; 4 lect hrs per wk)
Development from first principles. Application of Schrödinger equation, matrix representations, approximation methods.

Phys 5162. Introduction to Plasma Physics. (4 cr; prereq 5022, 5024 or #; offered alt yrs)
Magnetohydrodynamics and properties of collisionless plasmas, applications to magnetic field of Earth and sun and to plasma confinement. Transport phenomena and effects of collisions.

Phys 5201f,w-5202w. Thermal and Statistical Physics. (4 cr per qtr; prereq 3513 or equiv; 4 lect hrs per wk)
Principles of thermodynamics and statistical mechanics and selected topics from their application to kinetic theory; transport theory and phase transitions.

Phys 5211s. Introductory Solid-State Physics. (4 cr; prereq 5101, 5202 or equiv; 4 lect hrs per wk)
Properties of solids. Topics include vibrational and electronic properties of solids, diffraction of waves in solids and electron band structure. Other possible topics include optical properties, magnetic phenomena, superconductivity.

Phys 5231f-5232w-5233s. Introduction to Solid-State Physics. (4 cr per qtr; prereq grad or advanced undergrad in physical science or engineering, 1254 or 3254, 3512 or #; 4 lect hrs per wk)
Principles of solid physics for scientists and engineers. Crystal structure and binding; X-ray and neutron diffraction; phonons; thermal and dielectric properties of insulators; the free-electron model and band structure of metals; semiconducting behavior and magnetism. Other possible topics include superconductivity, ferroelectricity, optical phenomena, surface and interface properties, and departures from crystalline order.
Phys 5301s. Introduction to Nuclear Physics. (4 cr; prereq 5101 or equiv; 4 lect hrs per wk)
Structure of atomic nuclei; single-particle and collective models; interactions between elementary particles and nuclei and nucleus-nucleus interactions from very low up to relativistic energies; tests of fundamental conservation laws; fission and fusion reactions; astrophysical applications. Survey for nonspecialists and a first course for those planning to specialize in nuclear physics.

Phys 5371s. Introduction to Elementary Particle Physics. (4 cr; prereq 5101 or equiv; 4 lect hrs per wk)
Properties and interactions of the fundamental constituents of nature. Survey for nonspecialists and those intending to specialize in elementary particle physics.

Phys 5400H. Junior Honors Seminar. (1 cr; prereq upper div IT or CLA honors student, #; 1½ sem hrs per wk; may be taken no more than three times)
Seminar for upper division physics majors in the honors program, designed to prepare students for senior honors thesis projects and provide guidance in choice of future careers.

Phys 5401. Introduction to Contemporary Problems in Cosmic Ray and Space Physics. (4 cr; prereq #; primarily for students specializing in other branches of physics; offered alt yrs)

Phys 5410H. Senior Honors Seminar. (1 cr; prereq upper div IT or CLA honors student, #; 1½ sem hrs per wk; may be taken no more than three times)
A seminar for upper division physics majors in the honors program who are carrying out senior honors thesis projects.

Phys 5422. Introduction to Magnetostric Phys. (3 cr; prereq §5022, 5024 or equiv)
Physics of the magnetosphere and its interaction with solar wind; single particle motions, radiation belts, plasma convection; magnetic structure and currents; collective behavior, magnetohydrodynamic description of plasmas; discontinuities, boundary layers, shocks; plasma waves and instabilities.

Phys 5511. Topics in Physics for Biology and Medicine: Mechanics and Molecular Physics. (5 cr per qtr; prereq general physics, calculus; offered alt yrs)
Statics (forces in bones and joints). Exponential growth and decay. Statistical physics (entropy, reversibility, Boltzmann factor and Nernst equation, Brownian movement, free energy). Diffusion, bulk flow, and osmosis.

Phys 552w. Topics in Physics for Biology and Medicine: Electricity and Signals. (5 cr per qtr; prereq general physics, calculus; offered alt yrs)
Electricity and circuits (electrocardiogram, networks, nerve conduction); transducers, amplifiers; oscillators; feedback control; signal analysis (Fourier analysis, correlation functions, power spectra).

Phys 553s. Topics in Physics for Biology and Medicine: Light, Atoms, and Nuclei. (5 cr per qtr; prereq general physics, calculus; offered alt yrs)
Infrared, invisible, and ultraviolet light. X-rays (production, absorption, dosimetry). Nuclear medicine. Magnetic resonance imaging.

Phys 5561. Magnetism: Physics, Geophysics, and Engineering. (3 cr, §EE 5561, §Geo 5561; prereq 1253 or 1453; 3 lect hrs per wk)
Elementary statistical mechanics, rock magnetism, micromagnatic modeling. Applications of magnetism in geophysics, biomagnetism, magnetic sensors, and recording.

Phys 5600. Graduate Written Exam Seminar. (1 cr per qtr; 1 sem hr per wk)
Strategies for and practice in solving problems in advanced undergraduate physics. Intended primarily for first-year graduate students preparing to take the Graduate Written Exam in physics.

Phys 5801s. Modern Optics. (4 cr; prereq 5024 or #; 4 lect hrs per wk; offered alt yrs)
Modern theoretical and experimental optics, broadly defined to include, for example, radio astronomy. Matrix methods in geometrical optics including charged particle optics; optical detectors and noise; phenomena in intense coherent radiation including nonlinear effects.

Phys 5805. Contemporary Optics. (4 cr; prereq #; 4 lect hrs per wk)
Fundamentals of lasers, including propagation of Gaussian beams, optical resonators, theory of laser oscillation, electro-optic and acousto-optic modulation, and nonlinear optics.

Phys 5911-5912. Concepts in Physics. (4 cr per qtr; prereq general physics or #; 3 lect, 2 lab hrs per wk)
Overview of physics with emphasis on 20th-century developments. Primarily for secondary teachers and science majors wanting a summary review of physics.

Phys 5924. History of 19th-Century Physics. (4 cr, §HSci 5924; prereq general physics or #)
Experimental and theoretical discoveries in 19th-century physics (wave theory of light, atomic theory, heat, thermodynamics and statistical mechanics, electromagnetism and field theory) within context of educational, institutional, and political developments in Europe and the United States.

Phys 5925. History of 20th-Century Physics. (4 cr, §HSci 5925; prereq general physics or #)
Experimental and theoretical discoveries in 20th-century physics (birth of modern physics, special theory of relativity, old and new quantum theories) within context of educational, institutional, and political developments in Europe and the United States.

Phys 5940su, UC. Physics for High School Teachers: Experimental Foundations and Historical Perspectives. (4 cr per qtr [may be repeated for cr; no cr for physics grad or grad physics minor]; prereq completion of summer session 5940)
For physics and physical sciences teachers. Improves understanding of electricity and shows how the history of science can bring more activity and fun into teaching. Teachers follow the development of ideas, repeat historical experiments, and learn investigation techniques.

Phys 5950. Colloquium Seminar. (Cr ar; primarily for beginning grads and advanced undergrads in physics; prereq $; S-N only)
Colloquium of the School of Physics and Astronomy.
Phys 5961. Physical Science for Elementary School Teachers. (1-4 cr, [may be repeated for cr; no cr for physics undergrad or grad or for undergrad or grad physics minor]; prereq elementary school teacher recommended by participating school district) Development of in-depth understanding of physics topics relevant to elementary school teaching. Focuses on synthesis of mathematical concepts, problem-solving strategies, and model building to explain the physical world.

Phys 5970. Directed Studies. (1-5 cr; prereq #, ∆) Independent, directed study in physics in areas arranged by the student and a faculty member.

Phys 5980. Research Seminar. (1 cr; primarily for beginning grads and advanced undergrad majors in physics; 1 sem hr per wk) Introduction to the research activities of the School of Physics and Astronomy.

Phys 5990. Directed Research. (Cr ar; prereq 3rd yr, ∆) Problems, experimental or theoretical, of special interest to students. Written reports.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)
Phys 8081-8082. General Relativity
Phys 8121. Advanced Quantum Mechanics
Phys 8122. Relativistic Quantum Mechanics
Phys 8123. Relativistic Quantum Field Theory
Phys 8131. Symmetry and Its Applications to Physical Problems
Phys 8161. Atomic and Molecular Structure
Phys 8163-8164. Plasma Physics
Phys 8165. Advanced Topics in Plasma Physics
Phys 8200. Seminar: Condensed Matter Physics
Phys 8211. Equilibrium Statistical Mechanics
Phys 8212. Transport Theory
Phys 8216. Many-Body Theory
Phys 8221-8222-8223. Solid-State Physics
Phys 8232. Magnetism
Phys 8233. Superconductivity
Phys 8234. Techniques of Low-Temperature Physics
Phys 8235. Liquid and Solid Helium
Phys 8238. Advanced Topics in Solid-State and Low-Temperature Physics
Phys 8300. Seminar: Nuclear Physics
Phys 8311. Nuclear Structure
Phys 8312. Nuclear Reactions
Phys 8313. Relativistic Nuclear Many-Body Theory
Phys 8321. Advanced Topics in Nuclear Physics
Phys 8360. Seminar: Mass Spectroscopy
Phys 8370. Seminar: Elementary Particle Physics
Phys 8371-8372-8373. Elementary Particle Physics
Phys 8380. Advanced Topics in Elementary Particle Physics
Phys 8381-8382-8383. Modern Quantum Field Theory and Its Applications
Phys 8400. Seminar: Space Physics
Phys 8411-8412. Cosmic Ray and Space Physics
Phys 8421-8422. Solar and Magnetospheric Physics
Phys 8500. Plan B Project
Phys 8950. Seminar: Problems of Physics Teaching and Higher Education
Phys 8990. Research in Physics

Statistics (Stat)

Stat 1001. Introduction to Ideas of Statistics. (4 cr; prereq high school algebra) Controlled vs. observational studies; presentation and description of data; correlation and causality; sampling; accuracy of estimates; tests.

Stat 3011-3012. Statistical Analysis. (4 cr per qtr, prereq college algebra) Descriptive statistics; elementary probability; estimation; one- and two-sample tests; correlation; introduction to regression; ANOVA; randomized blocks; multiple comparisons; factorial experiments; multiple regression; goodness of fit; nonparametric methods; contingency tables; selected topics.

Stat 3091f,w,s. Introduction to Probability and Statistics. (4 cr, §5121, §5131; prereq differential and integral calculus) Elementary probability and probability distributions, sampling and elements of statistical inference.

Stat 5021. Statistical Analysis. (5 cr, §3012; prereq college algebra or #) Intensive version of 3011-3012; primarily for graduate students needing statistics as a research technique.

Stat 5091. Statistical Methods for Quality Improvement. (4 cr; prereq 3012 or 3091 or 5021 or 5122 or 5132, Math 1252) Application of statistical concepts of random variability and sampling, statistical process control, Shewhart and accumulative charting, analysis of plant data, applications of trend surface analysis, analysis of variance and design of experiments, quality improvement by reduction of random variability.
Stat 5121f-5122w. Theory of Statistics. (5 cr per qtr, §5131-5132-5133; prereq Math 1252)
Univariate and multivariate distributions, law of large numbers, sampling, likelihood methods, estimation and hypothesis testing, regression and analysis of variance, confidence intervals, distribution-free methods.

Stat 5131f-5132w-5133s. Theory of Statistics. (4 cr per qtr, §5121-5122; prereq Math 3252)
5131: Probability models, univariate and bivariate distributions, independence, basic limit theorems. 5132-5133: Statistical decision theory, sampling, estimation, testing hypotheses, parametric and nonparametric procedures for one- and two-sample problems, regression, analysis of variance. Treatment more mathematical than that in 5121-5122.

Stat 5201w. Sampling Methodology in Finite Populations. (4 cr; prereq 3091 or 5021 or 5121 or #)
Simple random, systematic, stratified, and unequal probability sampling. Ratio and regression estimation. Multistage and cluster sampling.

Stat 5271. Bayesian Decision Making. (4 cr; prereq §5122 or §5132)
Axioms for personal probability and utility. Elements of statistical decision theory. Bayesian analysis of linear models.

Stat 5301w,s. Designing Experiments. (5 cr, §5163; prereq 3012 or 5021 or 5133 or #)
Control of variation, construction, and analysis of complete and incomplete block, split plot, factorial, and other groups of similar experiments. Confounding, crossover, and optimum seeking designs.

Stat 5302f,s. Applied Regression Analysis. (5 cr, §5161; prereq 3012 or 5021 or 5133 or #)
Simple, multiple, and polynomial regression. Estimation, testing, and prediction. Stepwise and other numerical methods; examination of residuals; weighted least squares; nonlinear models; response surface. Experimental research and economic applications.

Stat 5401f. Introduction to Multivariate Methods. (4 cr; prereq 5133 or 5302)

Stat 5421. Analysis of Categorical Data. (4 cr, §5162; prereq 3012 or 5021 or 5133 or #)

Stat 5601w. Nonparametric Methods. (4 cr; prereq 5021 or 5122 or 5132 or #)
Necessary discrete and continuous probability distributions. Goodness of fit, sign tests, order statistics, rank tests for location and for scale, two-sample and k-sample comparisons, association. Methods and applications.

Stat 5890. Senior Paper. (2 cr; prereq sr Stat major)
Paper on specialized area, consulting project, or original computer program. Directed study satisfies senior project requirement for majors.

Stat 5900. Tutorial Course. (Cr ar; prereq #)
Study in areas not covered by regular offerings. Directed study.

Stat 5911, 5912, 5913. Topics in Statistics. (3 cr per qtr [may be repeated for cr with Δ]; prereq 3091 or 5021, #)
Topics vary.

For Graduate Students Only
(For descriptions, see Graduate School Bulletin)

Stat 5161-5162-5163. Applied Statistical Methods
Stat 8151-8152-8153. Mathematical Statistics
Stat 8162. Computational Statistical Methods
Stat 8171-8172-8173. Theory of Inference
8191-8192. Large-Sample Theory
Stat 8221. Topics in Sampling
Stat 8311-8312. Linear Models
Stat 8313. Topics in Experimental Design
Stat 8321. Linear and Nonlinear Regression
Stat 8331. Statistical Computing
Stat 8401. Topics in Multivariate Methods
Stat 8411-8412. Multivariate Analysis
Stat 8431. Theory of Categorical Data Analysis
Stat 8501-8502. Introduction to Stochastic Processes With Applications
Stat 8511-8512. Time Series Analysis
Stat 8601. Topics in Robust Methods
Stat 8611-8612. Nonparametric Inference
Stat 8731-8732. Statistical Decision Theory
Stat 8751-8752. Sequential Analysis
Stat 8801. Statistical Consulting
Stat 8900. Student Seminar
Stat 8901. Directed Readings and Research
Stat 8931-8932-8933-8934. Advanced Topics in Statistics